

MIKE TAMMARO
Activity Book

PHYSICS MATTERS

**An Introduction
to Conceptual
Physics**

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Activity Book

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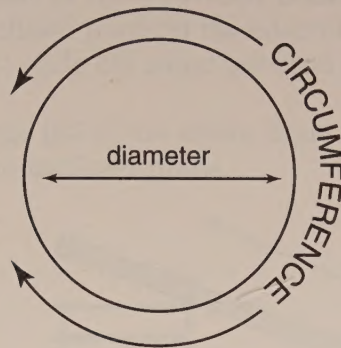
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Activity**1.1****Proportionality**

In this activity you will explore the concept of proportionality by measuring the circumference and diameter of four round objects, and graphing your results. The diameter of a circle is the distance across the circle, and the circumference is the distance around the circle.

**COLLECT MATERIALS**

You will need the following materials for this activity: a piece of string, a ruler, and four round objects.

TAKE MEASUREMENTS

Measure the diameter and circumference of four round objects and record the data in the table below. Wrap the string around the outside of the objects to find the circumference. Be sure to use the same units for each of your measurements.

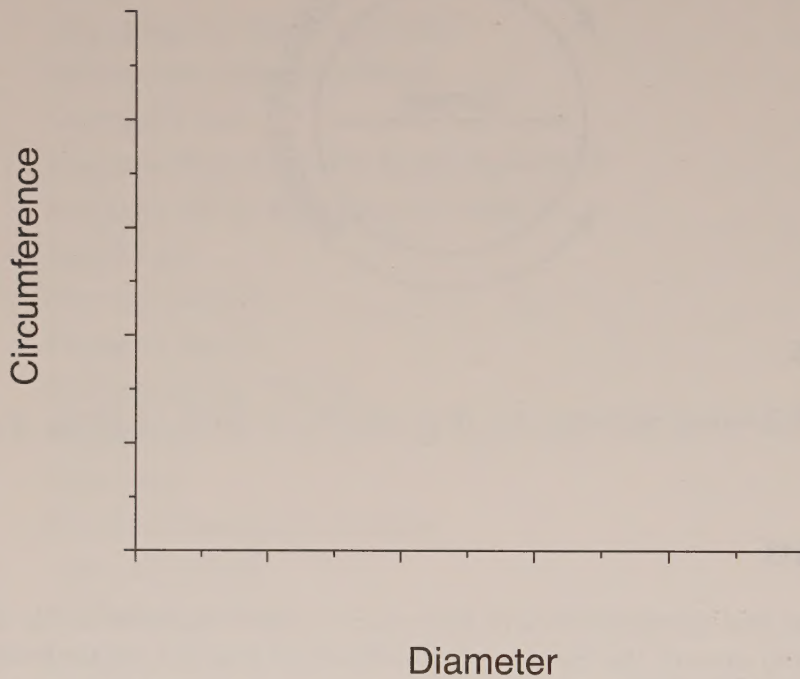
OBJECT	CIRCUMFERENCE	DIAMETER

What units (inches, centimeters, etc.) did you use for your measurements?

What trends do you notice in your data table?

PLOT YOUR DATA

Note the range of the values for circumference in the table. Mark the vertical axis with an appropriate scale. Do the same for the horizontal axis. Use the blank graph below to plot your data.



FIND THE SLOPE OF THE GRAPH

Use a ruler to draw a straight line that best fits the data. Find the *slope* of the graph. The slope of a graph is the vertical rise divided by the horizontal run.

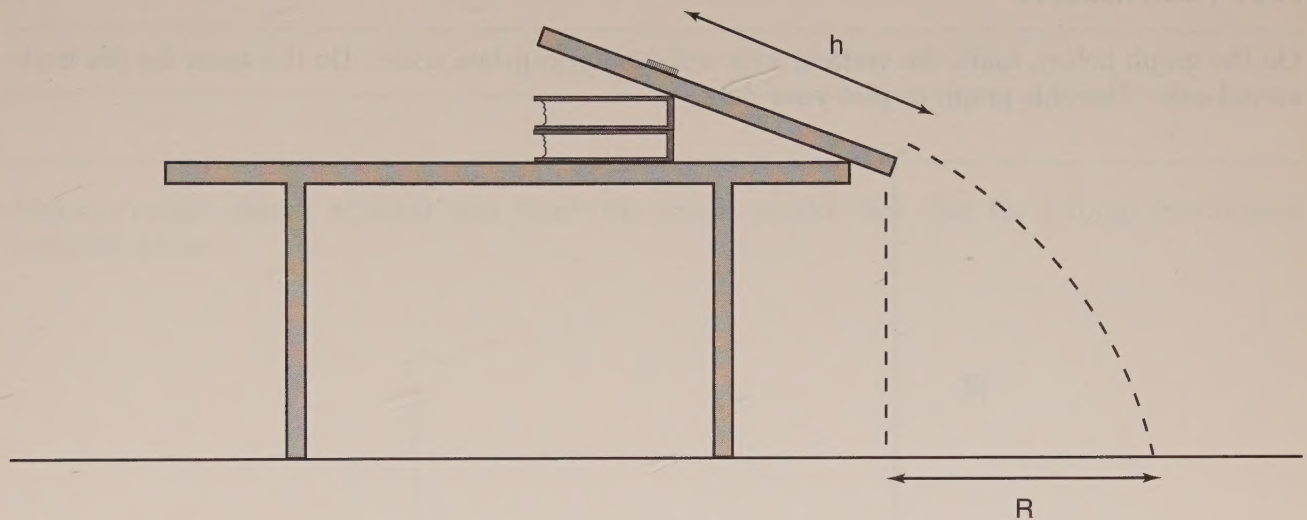
What is the slope?

If your data is well-fitted by a straight line, then we can say that the circumference of a circle is directly proportional to the diameter. Using the slope of your graph, write an equation that relates the circumference of a circle to its diameter:

Activity**1.2****A Scientific Experiment****COLLECT MATERIALS**

Find a coin, a smooth inclined plane (a hard-covered book propped up on one end will work just fine), and a ruler. Place the inclined plane at the edge of a desk or table. Be sure the incline is high enough so that the coin will slide off when released from rest.

We want to determine how the range (R) of the coin's flight depends on the height (h) at which it is released from the bottom of the inclined plane.

**MAKE A HYPOTHESIS**

Come up with a hypothesis for how the range will depend on the height. (Will the range be proportional to the height? Will the range be independent of the height?) Write your hypothesis below.

DO YOUR MEASUREMENTS

Release the coin, starting from rest, at five different values of h and measure the range. Do a few test trials first to get a feel for the measurements you will be making. If it is difficult to see exactly where the coin lands, you can rub some pencil lead on the coin and have it land on a piece of white paper. In this way, it will leave a clear mark when it lands.

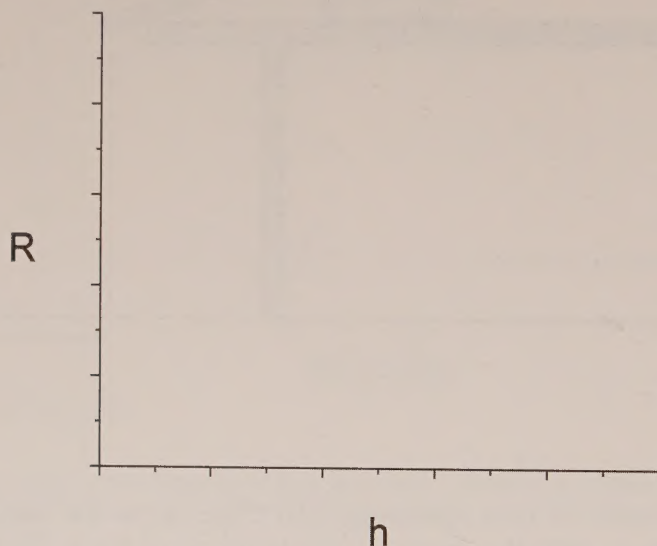
What units will you be using for the measurements? (cm, in, feet, etc.)

Record your data for the experiment in the table below.

h					
R					

PLOT YOUR RESULTS

On the graph below, mark the vertical axis with an appropriate scale. Do the same for the horizontal axis. Use this graph to plot your data.

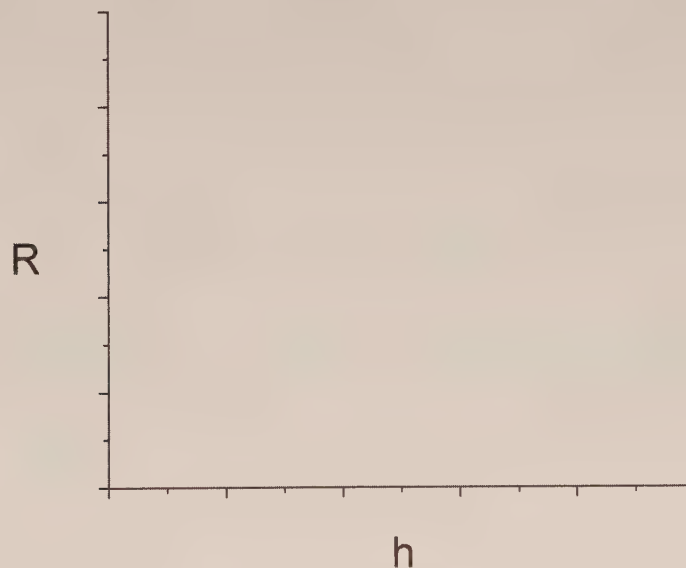


Do your results support your hypothesis? Why or why not?

There was friction between the coin and the inclined plane. Do you think that if there was no friction, the graph would look different? Explain your reasoning.

Suppose there was no friction and the inclined plane was very long, so that the coin was moving very fast when it reached the bottom of the plane. What effect would this have on your results?

Make a rough sketch of what you think the graph would look like for a long, frictionless inclined plane.



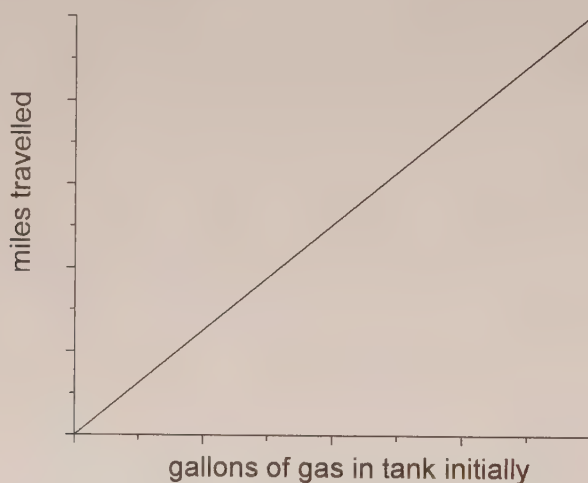
Activity**2.1****Graphic Language**

Mathematics is the language of science, and mathematical relationships can usually be expressed graphically. Most of the time, we are interested in how one quantity depends on another. In this case, a simple graph with horizontal and vertical axes will do the trick.

In this activity, you will be given two quantities and will be asked to make an *approximate* graph of how one quantity changes with the other. Afterwards you will state what kind of a mathematical relationship would be appropriate to represent your graph; direct, inverse, or power law. Review chapter two as necessary.

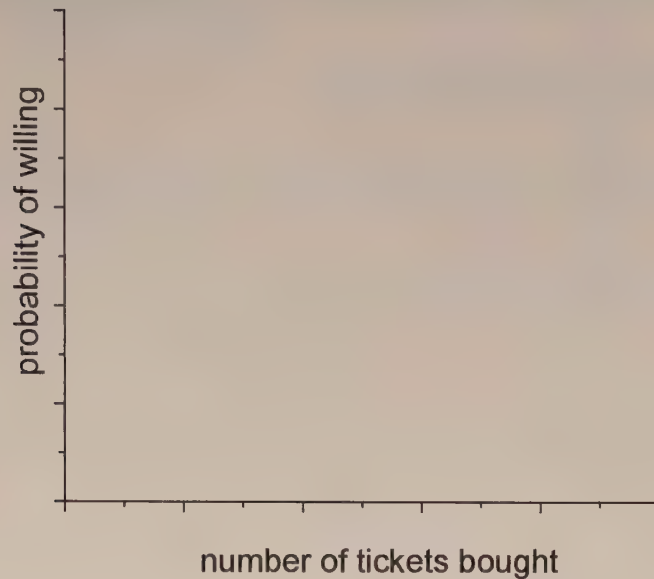
The following is an example to help you get started.

EXAMPLE: The more gas you have in your gas tank, the further you can drive. Make a graph of the distance you can travel versus the amount of gas in your tank.



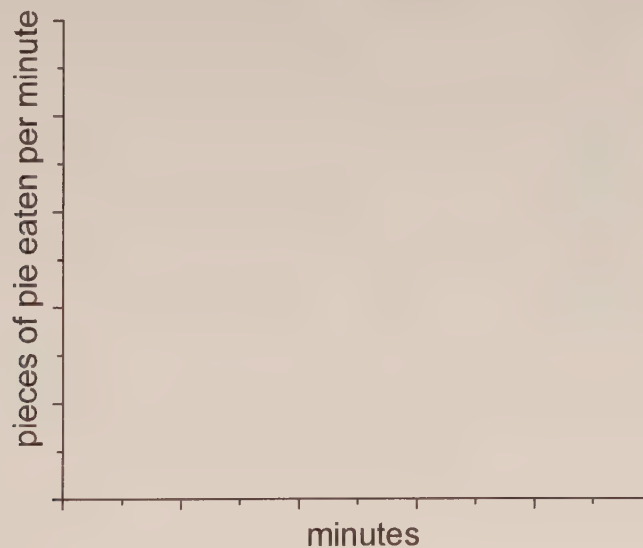
This is a *direct* relationship, so the graph is a straight line. We say that the number of miles traveled is *proportional* to the amount of gas in the tank. If you double the amount of gas in your tank, you can travel twice as far.

1. Suppose the jackpot of the state lottery is up to \$100,000,000 and you want to increase your chances of winning by buying multiple tickets. Make a rough graph of the probability of winning the lottery versus the number of tickets you buy.



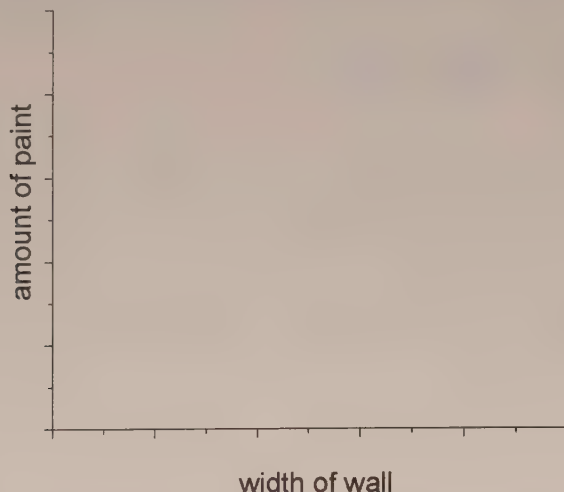
What kind of relationship is this?

-
2. You have been chosen by your classmates to represent the school in a pie eating contest. Your goal is to eat as many pieces of pie as possible. Your strategy is to eat as fast as possible until you cannot eat any more. Make a graph of the number of pieces of pie you eat per minute versus the time since you started eating.



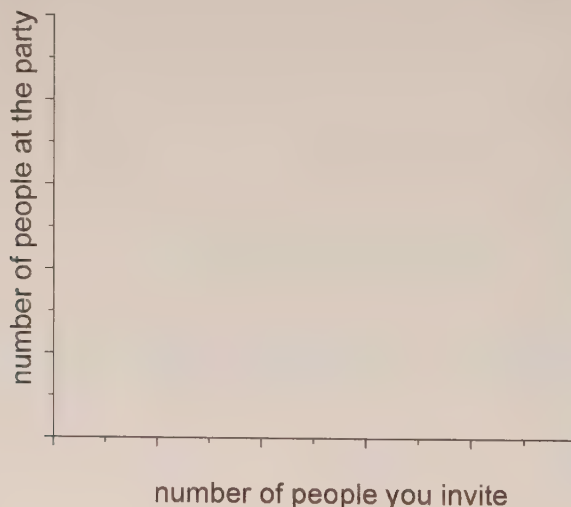
What kind of relationship is this?

3. Oddly enough, your specialty is painting square walls. In order to make preparing for a job easier, you would like to represent, graphically, the amount of paint you must bring to the job versus the width of the wall. Make this graph.



What kind of relationship is this?

4. You're throwing yourself a big birthday party. In order to make the party as big as possible, you tell each person you invite that they may bring five friends. Assuming everyone that is invited shows up, graph the number of people at the party versus the number of people you invite.



What kind of relationship is this?

Activity 2.2**Scalars and Vectors**

Any quantity that can be expressed as a single number is called a *scalar*. The amount of money in your pocket is a scalar quantity because it can be represented by a single number.

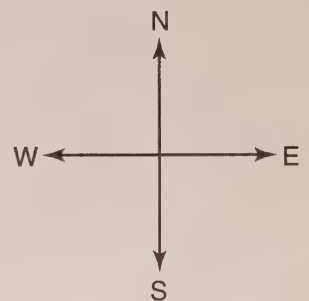
A *vector* is a quantity that has a direction. The location of the closest gas station is a vector quantity. For example, it may be 1.5 miles north. To uniquely specify the location, you need both the quantity (1.5 miles) and the direction (north).

Which of the following are vectors and which are scalars? (circle one)

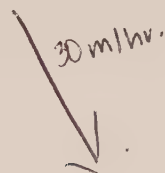
the correct time	vector	✓ scalar
the force exerted on a baseball by a bat	✓ vector	scalar
the top speed of your car	vector	✓ scalar
the location of Mt. Everest	✓ vector	scalar
the temperature of boiling water	vector	✓ scalar

Vectors can be represented by arrows. The length of the arrow is proportional to the magnitude (number). In this exercise, draw an arrow that best represents the velocity. Be sure that the lengths of the vectors are approximately correct with respect to each other.

a. 20 miles/hour, north



b. 30 miles/hour, southeast



c. 10 miles/hour, west

It is very common that two vectors must be added together. For example, two forces on an object may be represented as a single force that has the same effect as the two acting in combination. To add two vectors, connect the head of the first vector to the tail of the second. The sum of the two vectors is an arrow that connects the tail of the first vector to the head of the second.

In this exercise, you will be given two forces. Draw arrows to represent the two forces, and then draw an arrow that represents the sum of the two forces.

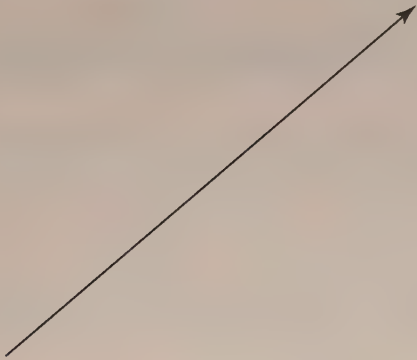
a. 10lbs to the right, 20lbs to the left

b. 10lbs up, 20lbs to the right

c. 30lbs to the right, 5lbs down

For the following vectors, draw two vectors (one horizontal and one vertical) whose sum would equal the vector shown.

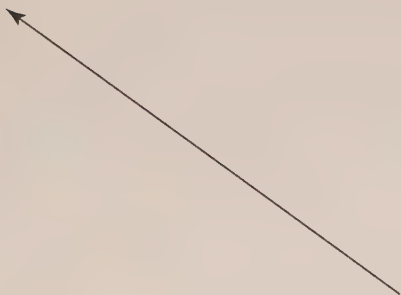
a.



b.



c.



Activity**3.1****Paper-henge**

This activity requires a sunny day, and a room with sun exposure for part of the day. First, cut out a triangular piece of paper and tape it to the middle of the window, so that the tip of the triangle casts a clear shadow somewhere in the room.

Tape an 8"x11" piece of paper in a location of the room so that the tip of the shadow is located in the center of the paper. Try to place the paper about one to two meters from the window. Make a small mark at the tip of the shadow and write the exact time next to it.

For the next hour, or until the shadow is off the paper, mark the location of the tip of the shadow every 5 minutes, labeling the time next to the mark. Staple the paper to this sheet before handing it in.

How far from the window was the piece of paper?

What would you expect if you left the paper in place, and traced the shadow again tomorrow at the same times? If you expect a different trace, draw a dotted line on the paper to show what you expect, and label it 'tomorrow.'

What would you expect if you left the paper in place, and traced the shadow again two months from now? If you expect a different trace, draw a dotted line on the paper to show what you expect, and label it 'two months from now.'

Name _____ Date _____ Class _____

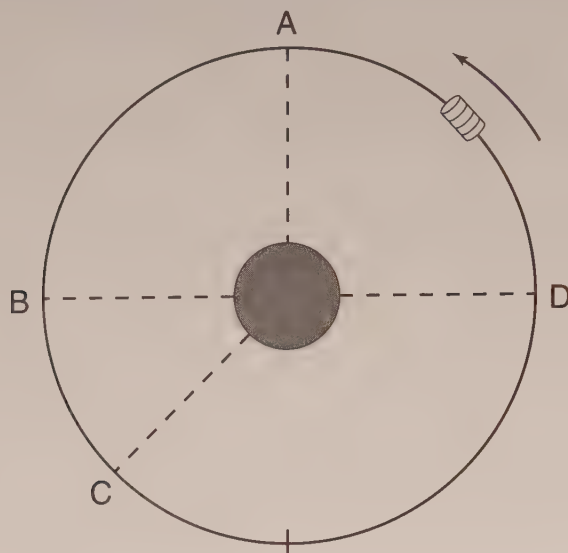
In what way is your 'dorm-henge' different from Stonehenge, as discussed in chapter 3?

Activity

3.2

Kepler's Second Law

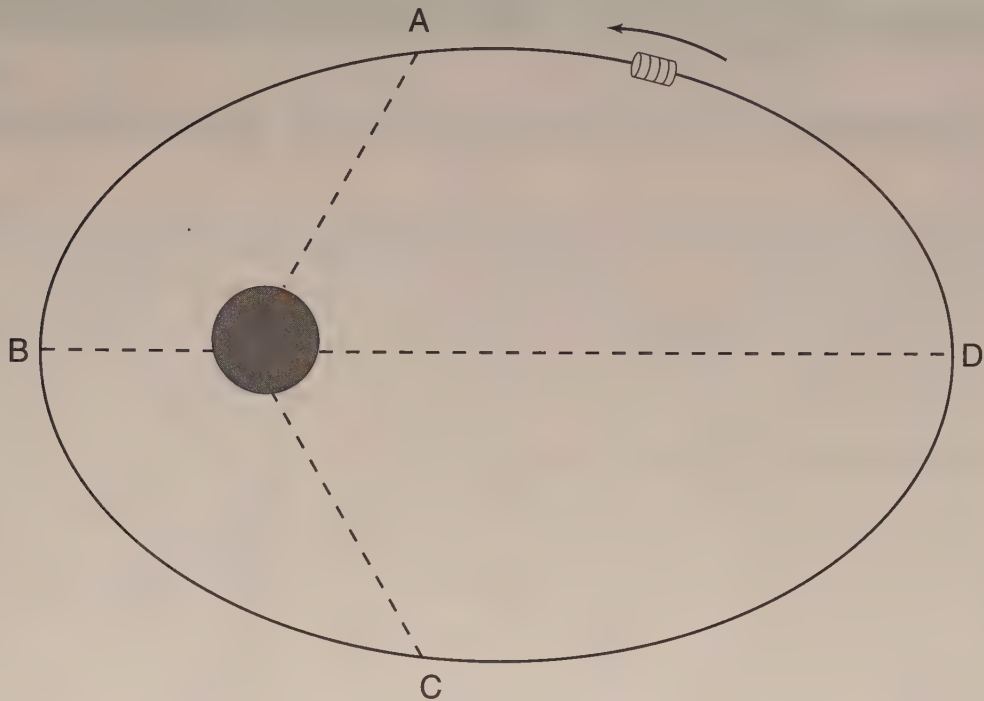
The following diagram represents a satellite executing a circular orbit around a planet.



If the satellite takes 12 hours to go from A to B, how long would you expect it to take to go from C to D? Explain your reasoning.

How long would you expect it to take to go from B to C? Explain your reasoning.

The following diagram represents a satellite executing an elliptical orbit around a planet.



If the satellite takes 10 hours to go from A to B, how long would you expect it to take to go from C to D? Explain your reasoning.

How long would you expect it to take to go from B to C? Explain your reasoning.

Activity 3.3**Speed, Distance, and Acceleration**

A car starts from rest and accelerates at a rate of 2 m/s per second for 10 seconds. For the next 10 seconds, the car maintains a constant speed. For the next 20 seconds, the car decelerates (accelerates backwards) at a rate of 1 m/s per second, until coming to a complete stop. The total elapsed time of the trip is 40 seconds.

When you answer the following questions, be sure to show your calculations.

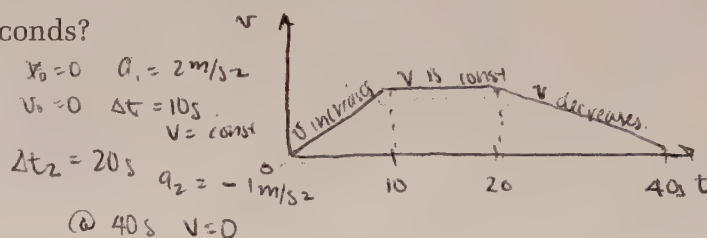
How far did the car travel in the first 10 seconds?

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$x = 0 + 0 + \frac{1}{2} 2(10^2)$$

$$= \frac{1}{2} (200)$$

$$x = 100 \text{ m}$$



How fast was the car traveling after the first 10 seconds?

$$v = v_0 + a \cdot t$$

$$v = 0 + (2 \text{ m/s})(10)$$

$$= 20 \text{ m/s}$$

How far did the car travel between 10 and 20 seconds? 200 m

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$x = 100 + 0(t) + \frac{1}{2} 2 \text{ m/s} (10^2)$$

$$= 100 + \frac{1}{2} (200)$$

$$= 100 + 100$$

$$200 \text{ m}$$

* How far did the car travel during the last 20 seconds?

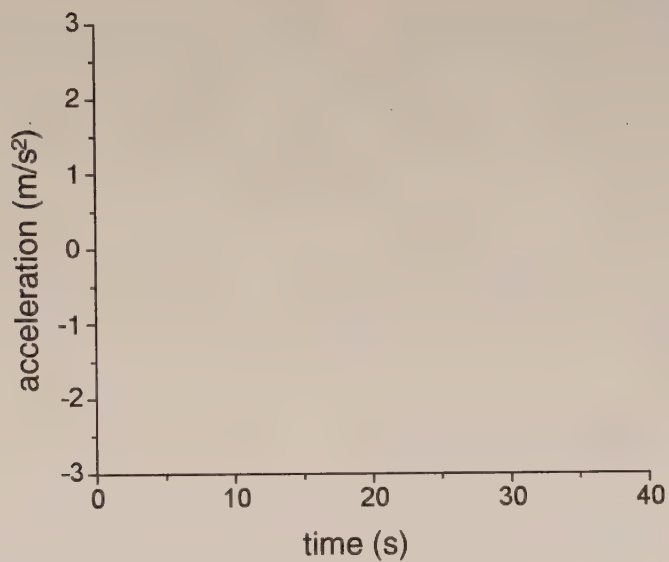
$$X = X_0 + v_0 t + \frac{1}{2} a t^2$$

$$X = 300 + 0(1) + \frac{1}{2} (-1)(20^2)$$

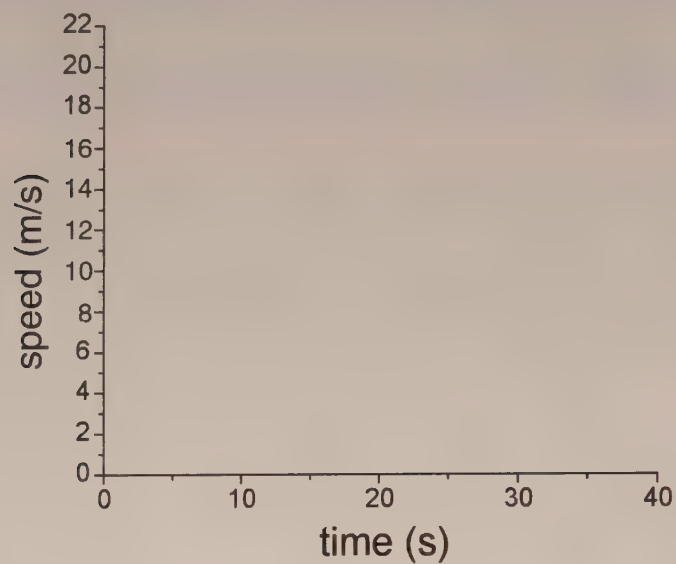
$$= 300 + \frac{1}{2} 400(-1)$$

:

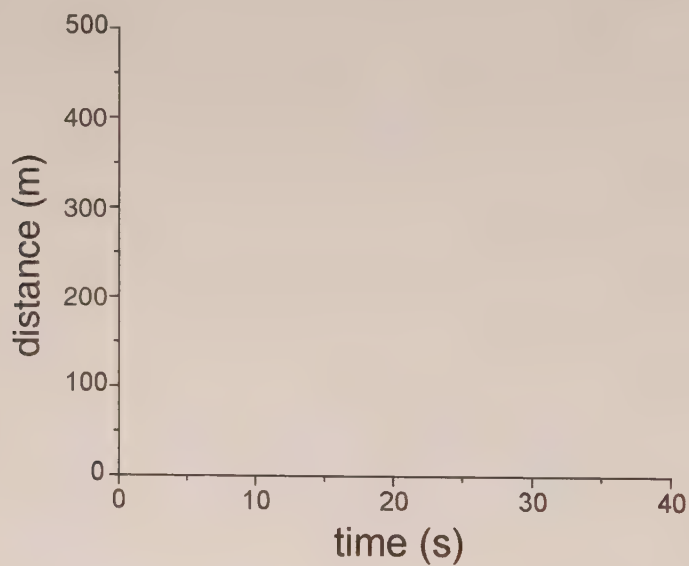
Make a graph of the acceleration versus time for the entire trip.



Make a graph of the speed of the car versus time.



Make a graph of the distance traveled versus time.



Activity**3.4****Free Fall**

The acceleration of gravity is equal to 9.8 m/s^2 , or 32 ft/s^2 . In this activity you will investigate freely falling bodies. You may need to use the following equations:

$$v = at \text{ and } D = \frac{1}{2}at^2 \text{ (which can be written as } t = \sqrt{\frac{2D}{a}})$$

Suppose you drop a coin from rest, at eye level. Use the appropriate equation above and calculate the time it should take for the coin to fall to the ground. The distance from the ground to eye level is approximately your height.

Observe a clock or watch that displays seconds. Count the seconds in your head to get a feel for how long one second is. Stand up and hold a coin at eye level and drop it. How long would you say it took to fall to the ground? Does the time you calculated above seem reasonable?

Get a loosely crumpled piece of tissue or bathroom paper and drop it from eye level. How long would you say it took to fall to the ground? Did it take more or less time than the coin? (If you can't tell, then drop them simultaneously.)

According to the equation $t = \sqrt{\frac{2D}{a}}$, all things dropped from the same height would hit the ground at the same time. Would the coin and the tissue paper hit the ground at the same time when dropped simultaneously from eye level? If not, why not?

Try dropping the coin and the tissue paper simultaneously from a height of 6 inches to a tabletop. Can you tell which one hits first? It should be difficult to tell. Why, when dropped from a smaller distance, is the time almost the same?

Activity

4.1

Newton's First Law

Close your eyes and try to feel all of the forces acting on you. Write them down in the space below.

According to Newton's First Law: A moving object will continue moving in a straight line at a constant speed, and a stationary object will remain at rest, unless acted upon by an unbalanced force.

Assuming that you are stationary, Newton's first law says that you must be acted on by a *balanced* force. In the context of the forces you listed above, what does it mean that you are acted upon by a *balanced* force?

Drop something and watch it fall. Does it move in a straight line? _____ Does it move with constant speed? _____

What does Newton's First Law tell you about the force(s) acting on the object as it falls?

Name _____ Date _____ Class _____

Imagine being in a car traveling along a straight road at constant speed. List all of the forces acting on the car.

If the car is moving in a straight line and at constant speed, the forces must be balanced. What does that tell you about the forces that you listed above?

Now suppose the driver of the car applies the brakes, and the car begins to slow down. List all of the forces acting on the car.

Are the forces balanced, or unbalanced now? What does that tell you about the forces acting on the car?

Activity**4.2****Newton's Second Law**

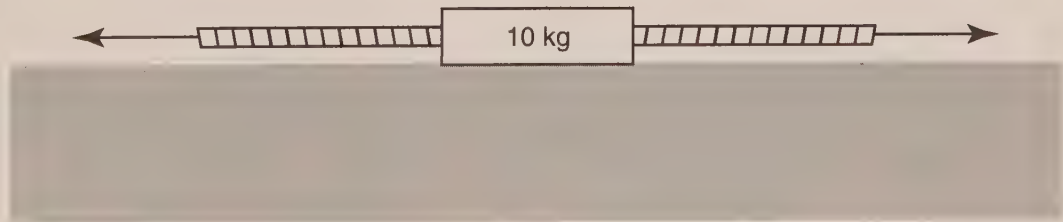
A force of 4.45 newtons is equal to about one pound of force. A mass of one kilogram has a weight of 9.8 newtons on the surface of the Earth.

What is your weight in newtons?

What is your mass in kilograms?

If you travel to the moon, would your weight, your mass, or both change?

Suppose there is a 10kg object on a frozen pond. One rope is pulling it to the right, and one to the left.



Fill in the missing information in the table.

Force pulling right	Force pulling left	Acceleration	Mass
10N	10N	0 m/s ²	10kg
53N	3N	10m/s ²	5kg
5N	45 4N	1m/s ²	1kg
100N	50N	2m/s ²	25 kg

* -50 N

3N

-10 m/s²

5kg

-50

What is the difference between speed and velocity?

What does it mean for an object to be accelerating to the right?

If an object is accelerating, is it necessarily moving? Explain.

If an object is moving, is there necessarily a force on that object? Explain.

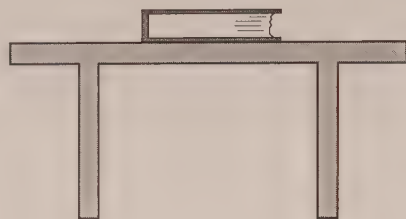
Name _____ Date _____ Class _____

If an object has no acceleration, can there be forces acting on that object? Explain.

Activity**4.3****Newton's Third Law**

Newton's third law states: *For every action (force) there is an equal and opposite reaction (force).* Thus, all forces come in pairs. There is an even number of forces in the universe. In this activity you will be given a variety of situations where forces are acting. When you are asked for a reaction force, state the force, and its direction.

Consider the forces on your textbook as it sits on a table. Assume that your textbook weighs 12 Newtons.



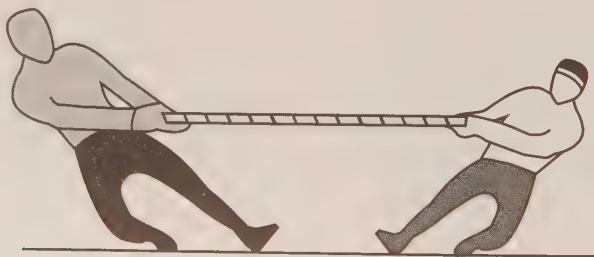
The table is pushing up on the book with a force of 12 Newtons. What is the reaction force?

the book is pushing down on the table

Gravity is pulling down on the book with a force of 12 Newtons. What is the reaction force?

book pulling up on the earth

Let's consider a different situation. A man is having a tug-of-war contest with a young boy. The mass of the rope is negligible. In an attempt to pull the boy over the line, the man pulls suddenly with a force of 70 pounds.



The man is pulling on the rope with a force of 70 pounds. What is the reaction force?

Provided the rope is not slipping in the boy's hand, what is the magnitude of the force of the rope pulling on the boy?

You are riding your bicycle along a straight stretch of road. You are accelerating forward, so your speed is increasing.

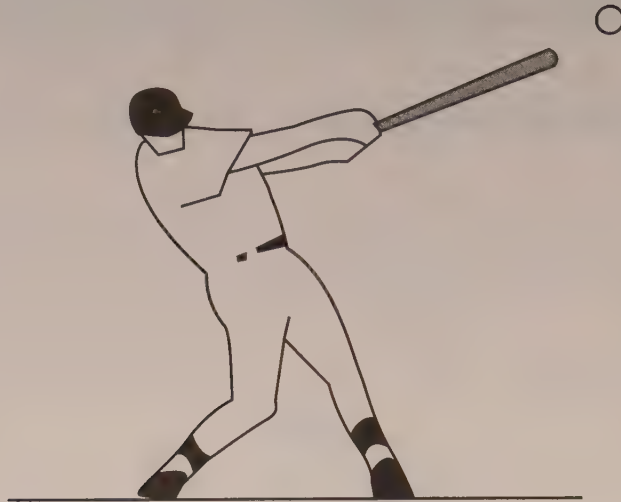


You push down on the pedal with a force of 600 Newtons. What is the reaction force?

The road is pushing forward on your rear tire with a force of 500 Newtons. What is the reaction force?

Air resistance is pushing back on you with a force of 300 Newtons. What is the reaction force?

A baseball player swings at the ball and hits a home run.



At one moment while in contact with the bat, the bat pushes on the ball with a force of 100 pounds. What is the reaction force?

While in the air, the force of gravity on the ball is 5 ounces. What is the reaction force?

Activity**5.1****Gravity of the Planets**

In this activity, you will calculate your weight on all of the planets in our solar system.

The following table contains the mass of the planets as a fraction of the mass of the Earth. It also contains the radius of the planets as a fraction of the Earth's radius.

PLANET	MASS	RADIUS	YOUR WEIGHT
Mercury	0.055	0.38	
Venus	0.86	0.95	
Earth	1.0	1.0	
Mars	0.11	0.53	
Jupiter	320	11	
Saturn	95	9.5	
Uranus	15	4.1	
Neptune	17.2	3.9	
Pluto	0.002	0.24	

The masses are measured in Earth mass units, rather than kilograms. According to the table, Jupiter is 320 times more massive than the Earth. The radii are measured in Earth radius units, so Jupiter has a radius 11 times that of the Earth.

The force of gravity can be calculated by Newton's law of gravitation. Your weight is proportional to a planet's mass divided by the radius of the planet squared. As long as we use the Earth units, it is easy to find your weight on another planet: Multiply your weight on Earth by the mass of the other planet and divide by the other planet's radius squared.

CALCULATE YOUR WEIGHT ON MERCURY

$$W = (\text{weight on earth}) \times \frac{\text{mass of mercury}}{(\text{radius of mercury})^2} = (\quad) \times \frac{0.055}{(0.38)^2} =$$

Enter this result into the last column in the table.

CALCULATE YOUR WEIGHT ON THE REST OF THE PLANETS

Following the above example, use a piece of scrap paper and a calculator to find your weight on all the planets in the solar system. Enter your results into the table.

ANALYZE YOUR RESULTS

Compare your weight on the Earth to your weight on Venus. It should be a little less than your weight on the Earth. Are you surprised by this result? Explain.

On which planet would you weigh only a little bit more than you do on the Earth?

Does this planet have about the same size as the Earth? What accounts for the fact that you have about the same weight on this planet?

On which planet are you the lightest?

What accounts for the fact that you are lightest on this planet?

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Based on the information in the table only, do you think the planets are all made of the same material? Explain.

You're heavier on Neptune than on Saturn, even though Saturn is bigger. Would this still be true if Saturn and Neptune were made of the same material? Explain.

Activity**5.2****Gravity****TAKING A TRIP TO THE MOON**

Suppose you travel in a straight line from the surface of the Earth to the surface of the Moon. At all times you will experience two gravitational forces; the gravitational pull from the Earth and the gravitational pull from the Moon. The Earth's mass is approximately 100 times the Moon's mass.



Suppose you are on the line connecting the center of the Earth to the center of the Moon, and you are exactly $1/2$ way between them. If the pull of Earth's gravity on you is 1 Newton, what is the pull of the Moon's gravity?

Suppose now that you move along the line until the distance to the center of the Earth is three times the distance to the center of the Moon.

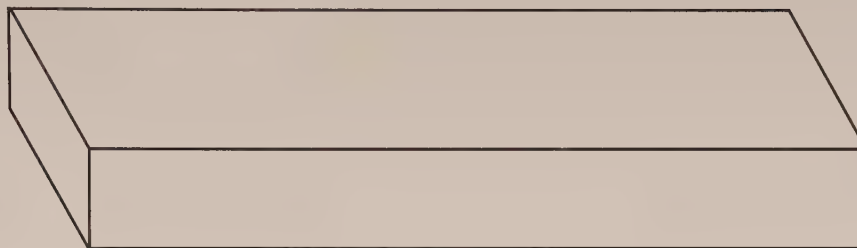
What is the force of gravity on you due to the Earth?

What is the force of gravity on you due to the Moon?

How much closer to the center of the Moon would you have to be, so that the pull of the Moon and the pull of the Earth cancel each other out?

TAKING A WALK ON A RECTANGULAR PLANET

Imagine a hypothetical planet which has rectangular dimensions. This planet is large enough so that you'll feel enough gravity to keep your feet on the ground.

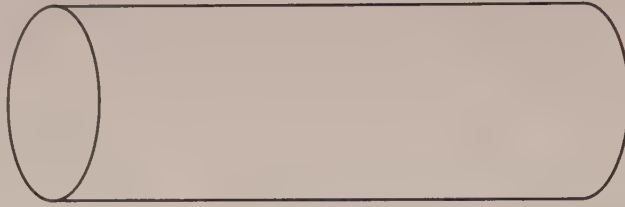


Where would you stand on this planet so that you would feel the lightest? Explain your reasoning and mark the figure with an L at the location.

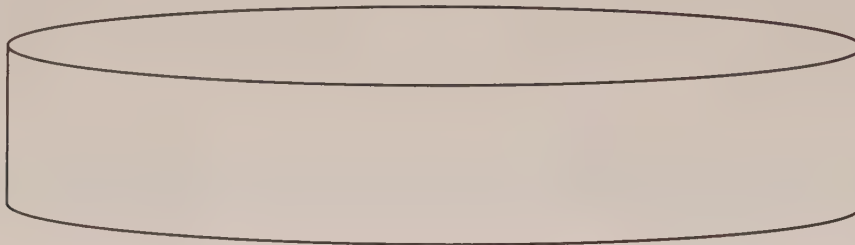
Where would you stand on this planet so that you would feel the heaviest? Explain your reasoning and mark the figure with an H at the location.

A CYLINDRICAL PLANET

Mark the cylindrical planet with an H and an L for the places where you would feel heaviest and lightest.



Do these locations depend on the relative height of the cylinder?



Activity**5.3****Influence of the Sun**

Most everyone knows that the Earth executes a near-circular orbit around the Sun. The force of gravity between the Earth and the Sun is responsible for the circular motion.

INVESTIGATE AND RESEARCH

Using your textbook, or any other resources you have available to you, look up the following quantities and write them in the space provided. (Distances should be in meters and masses should be in kilograms.)

The mass of the Sun _____

The mass of the Earth _____

The distance between the Sun and the Earth _____

The mass of your body _____

CALCULATE FORCES

The force between two masses is given by Newton's law of universal gravitation. In equation form, this law reads

$$F = G \frac{m_1 \times m_2}{d^2}$$

Review this law in chapter 5 if you need a refresher. If the masses are in kilograms, and the distance is in meters, the force will be in Newtons. (The gravitational constant G can be found in chapter 5.) Answer the following questions. (Be sure to show your calculations.)

What is the force of gravity between the Earth and the Sun?

What is the force of gravity between you and the Sun?

How many Newtons are there (approximately) in one pound?

If someone pushed on you with a force equal to the gravitational force between you and the Sun, would you feel it? _____

CALCULATE ACCELERATIONS

Newton's second law (chapter 4) allows us to calculate the acceleration due to a net force.

Newton's second law reads $a = \frac{F}{m}$.

What is the acceleration of the Earth due to the gravitational pull of the Sun?

What is the acceleration of your own body due to the gravitational pull of the Sun?

What is the acceleration of the Sun due to the gravitational pull of the Earth?

DISCUSSION AND QUESTIONS

The acceleration of the Earth and your own acceleration should be identical. Can you give an explanation of why this *must* be true without discussing forces?

The gravitational pull of the Sun on your own body is certainly not the only force acting on you. But the force we were supposed to use in Newton's second law is the *net force* on you. Why was it OK to treat the gravitational pull of the Sun on your body as the *net force* when calculating your acceleration?

What is the direction of the acceleration of the Earth?

Based on your answer to the last question, why isn't the Earth getting any closer to the Sun?

Activity**5.4****Weightless?**

In this activity we are going to calculate the force of gravity on an 80 kilogram person in three different situations. In all three cases you will need to use Newton's law of universal gravitation:

$$F = G \frac{m_1 \times m_2}{d^2}$$

RESEARCH AND COLLECT DATA

Using your textbook, or any other resources you have available to you, look up the following quantities and write them in the space provided. (Distances should be in meters and masses should be in kilograms.)

What is the radius of the Earth? _____

What is the height of Mt. Everest? _____

What is the mass of the Earth? _____

What is the altitude of a typical Space Shuttle orbit? _____

What is the gravitational constant, G ? _____

CALCULATE FORCES

Use Newton's law of universal gravitation to calculate the force on an 80 kilogram person in the three different situations. Your answer should be in Newtons.

What is the force of gravity on the 80 kilogram person when he/she is standing on the surface of the Earth?

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What is the force of gravity on the 80 kilogram person when he/she is on the top of Mt. Everest?

What is the force of gravity on the 80 kilogram person when he/she is orbiting in the Space Shuttle?

DISCUSSION AND QUESTIONS

In which location is the gravitational force the greatest? Why?

In which location is the gravitational force the least?

Does the fact that the gravitational force is weaker when the person is in the Space Shuttle account for the fact that the person feels *weightless* there? Explain.

Activity**6.1****Momentum: Mass Times Velocity**

The momentum of an object is equal to its mass times its velocity. In this activity you will estimate the momentum of a variety of objects. You may have to do some research to find the masses and speeds of the objects described. The mass should be in kilograms, and the speed should be in meters per second.

For reference: A weight of 1 pound is approximately equivalent to a mass of $1/2$ kilogram. A speed of 1 mile per hour is approximately equal to $1/2$ meter per second.

EXAMPLE: What is the momentum of a sports car driving down the highway?

The speed is probably about 60 miles/hour, or 30 meters per second. The weight of a sports car is about 3000 pounds, or 1500 kilograms.

$$\text{Momentum} = (1500 \text{ kg}) \times (30 \text{ m/s}) = 45,000 \text{ kg m/s}$$

1. What is the average momentum of a male sprinter setting a new world record in the 100 meter dash?
2. What is the momentum of a mosquito flying across the room?

3. What is the momentum of the Moon with respect to the Earth? (To determine the speed of the Moon, you will have to find the distance for one complete orbit, divided by the time it takes to orbit the Earth once.)

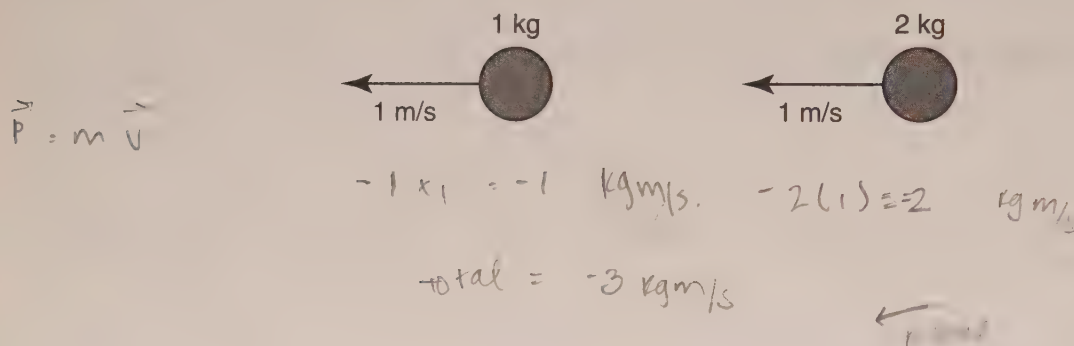
4. What is the momentum of a major league fastball? (A baseball pitched very fast.)

Activity 6.2**Adding Momentum**

Sometimes it is of interest to calculate the momentum of more than one object. The momentum of two or more objects is simply the sum of their individual momenta. Be careful though, because momentum has a direction.

In each of the following exercises, you will be shown two or more masses. Their speed and mass will be indicated, and the direction of the velocity will be indicated by an arrow. For each system, determine the total momentum and draw an arrow to indicate its direction.

1.



2.

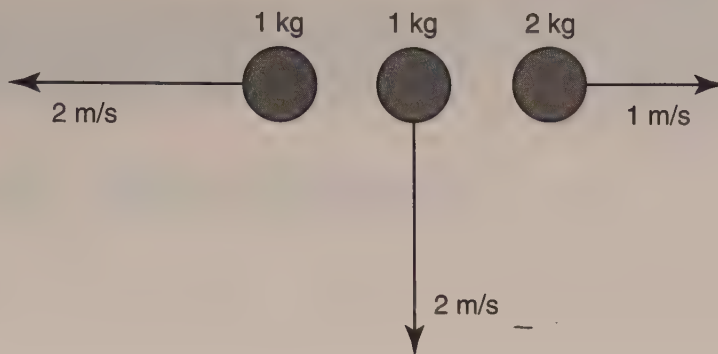


$$-2(5) = -10 \text{ kgm/s}$$

$$2(5) = 10 \text{ kgm/s}$$

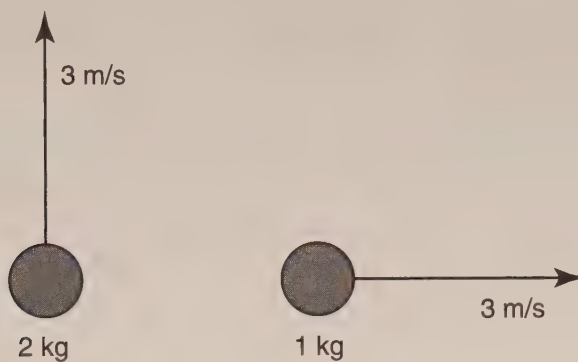
$$\text{total} = -10 + 10 = 0 \text{ kgm/s}$$

3.

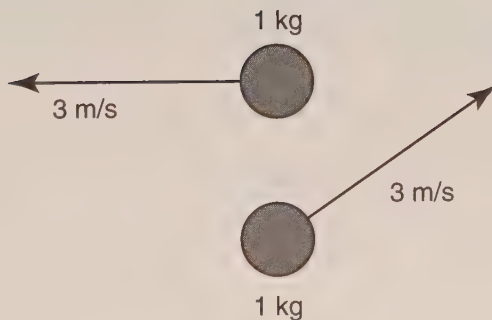


For the following situations, the total momentum may not be exactly vertical or horizontal. In this case, *estimate* the total momentum and draw an arrow in its direction.

4.



5.



Activity**6.3****Cushioning Your Fall**

If you were to accidentally fall off a roof, or high ladder, you would consider yourself very lucky if there happened to be a mattress waiting on the ground to *cushion* your fall. What is it, exactly, about the cushioning in the mattress that makes the fall less dangerous? What is it that hurts you when you fall?

What makes an impact hurt is a combination of the force exerted on you and how that force is distributed over your body. An impact will tend to hurt more if the force is large or if it is distributed over a small area. Football helmets have both a rigid outer shell (which tends to distribute the force over a larger area) as well as cushioning (which tends to reduce the force). In this activity, we will try to determine why cushioning reduces the impact force during collisions.

Consider dropping an egg from a window in your house so that it hits the ground with a speed of 10 meters/second. A typical egg weighs about 7 oz, or about 1/4 kilogram.

What is the momentum of the egg just before it hits the ground?

If the egg hits the concrete sidewalk, it will take about $1/100^{\text{th}}$ of a second to stop completely. What is the force the sidewalk exerts on the egg during this impact? (See the section in chapter 6 titled *Momentum* and *Newton's Laws*.)

Convert your answer to pounds. (1 pound is approximately equal to 4 Newtons.)

Now suppose the egg lands on a fluffy pillow instead of the concrete. Let's assume that the egg takes $1/20^{\text{th}}$ of a second to stop when it lands on the pillow. What is the force the pillow exerts on the egg during this impact?

Convert your answer to pounds.

Do you think the egg will break in either case?

Is the change in momentum greater, less, or the same when the egg lands on the pillow?

What does the cushioning do, exactly, that makes the force less?

Activity**6.4****Conservation of Momentum**

According to chapter 6, it takes a force to change an object's momentum. Consider a bottle of water sitting stationary on your kitchen counter. There are certainly forces on this bottle of water. Why doesn't its momentum change? (Review chapter 6 if necessary.)

Let's consider a collision between two hockey pucks on a frictionless ice surface.



When they collide, puck one pushes on puck two and puck two pushes back on puck one. What does Newton's third law tell us about these forces?

If the two hockey pucks are taken together as a single system, do the collision forces change the total momentum of the system? Why?

Chapter 6 discusses *conservation of momentum*. If you slide your textbook across the floor, it will stop due to friction. Clearly the momentum of the book has changed, thus the momentum of the book was not conserved. Under what conditions will the momentum of a system be conserved?

Activity 6.5

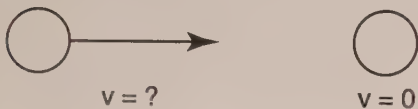
Collisions

Consider a collision between two hockey pucks on a frictionless ice surface. Provided there are no external forces on the system (friction or bouncing into the boards etc.), the momentum of the system is the same before and after the collision. In this activity you will be given before and after diagrams of colliding pucks. In some cases they will stick together and in some cases they will not. Fill in the missing information. You will have to use the principle of conservation of momentum. For simplicity, you can assume the pucks have a mass of 1 kilogram.

1.

BEFORE

AFTER



$$p_{\text{before}} = (1 \text{ kg})v + 1 \text{ kg}(0)$$

$$= 1 \text{ kg}v$$

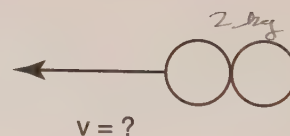
$$p_{\text{after}} = (1 \text{ kg})(0) + (1 \text{ kg})(3)$$

$$= 3 \text{ kg m/s}$$

$$1 \text{ kg}v = 3 \text{ kg m/s}$$

$$v = 3 \text{ m/s}$$

2.



$$1 \text{ kg}(2 \text{ m/s}) + 1 \text{ kg}(-4 \text{ m/s})$$

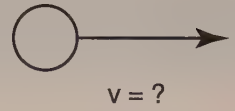
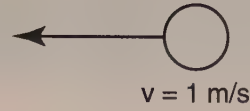
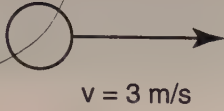
$$= 2 - 4 = -2 \text{ kg m/s}$$

$$-2 \text{ kg m/s}$$

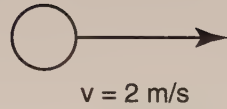
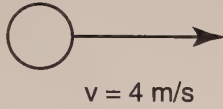
$$-2 \text{ kg m/s} = 2 \text{ kg}v$$

$$v = -1 \text{ m/s}$$

3.



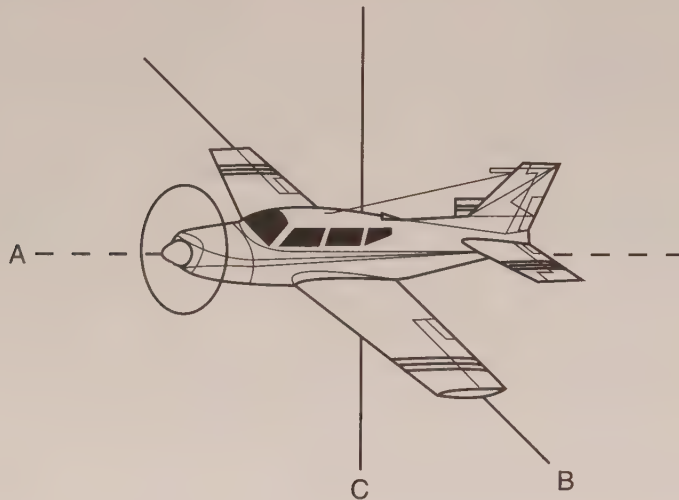
4.



Activity**7.1****Axis of Rotation**

Whenever a body rotates, it rotates about a specific *axis of rotation*. The axis of rotation is an imaginary line that passes through points of the body that do not move when the body rotates. A familiar example is the axis of rotation of the Earth. As the Earth spins, points near the equator move in a circular motion. However, imagine an imaginary line connecting the North and South poles. Points along this line do not move as the Earth rotates. This imaginary line defines the axis of rotation of the Earth.

Consider the following diagram of an airplane with three lines drawn through it.



1. If the airplane turned to the right, without banking, which line would best represent the axis of rotation? _____
2. If the airplane banked to the left, without turning right or left, which line would best represent the axis of rotation? _____
3. If the airplane turned upwards, which line would best represent the axis of rotation? _____
4. Suppose the airplane simultaneously turned left and banked left. On the diagram, draw the axis of rotation for this maneuver.

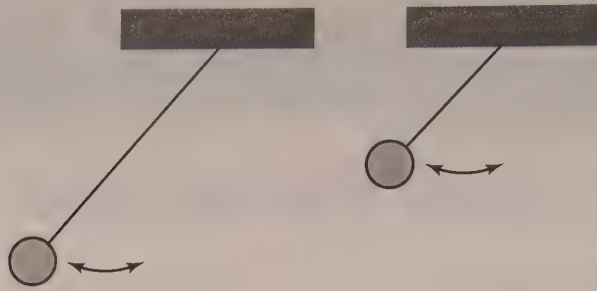
Activity**7.2****Period and Frequency**

Some objects seem to rotate "faster" than others. In that the Earth rotates once every 24 hours, while the wheels of a fast-moving car may rotate many times in a single second, we may be tempted to say that the wheels of the car rotate "faster" than the Earth. A more precise statement would be to say that the *frequency* of the wheel's rotation is higher than the *frequency* of the Earth's rotation. Frequency is the number of rotations in a given amount of time. The *period* is the time it takes for a complete rotation. Hence, period and frequency are inversely related. A rotation that has a high frequency has a short period.

(The correct adjectives to characterize frequency are *high* and *low*. The correct adjectives to characterize period are *long* and *short*.)

Fill in the blanks in the following sentences:

1. The period of the second hand of a clock is _____ than the period of the minute hand.
2. The frequency of the Earth's rotation about its axis is _____ than the frequency of the Moon's rotation about the Earth.
3. Consider a fast-moving bicycle. The period of the pedal's rotation is _____ than the period of the wheel's rotation.
4. The frequency of occurrence of New Year's Eve is _____ the frequency of occurrence of Thanksgiving.
5. The frequency of occurrence of the Olympic Games is _____ the frequency of occurrence of April Fool's Day.

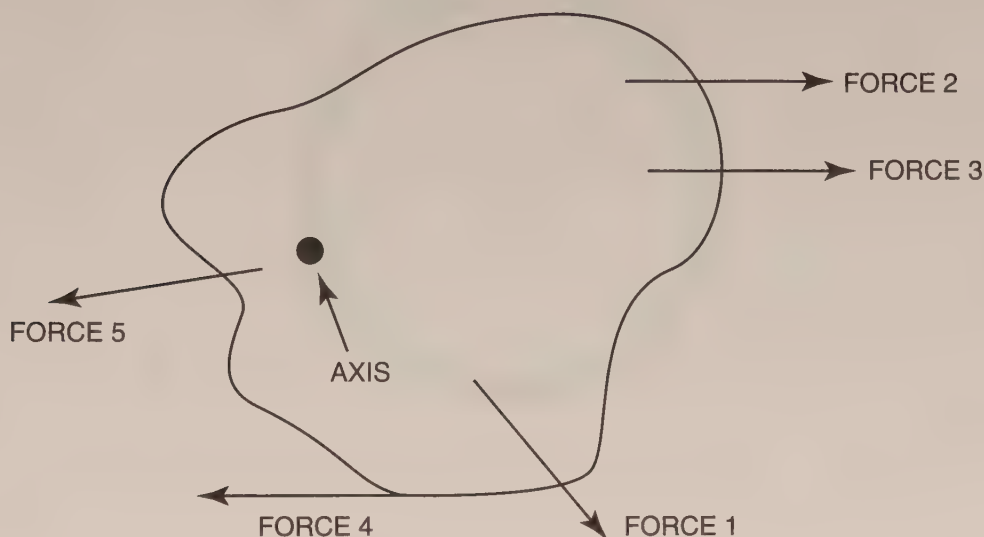


Which do you expect to have a longer period, a short pendulum or a long one? (If you don't know, do an experiment to find out.) Explain.

What has a higher rotation frequency, a rotating compact disc, or the carousel of your microwave oven? (If you don't know, check it out!)

Activity**7.3****Torque**

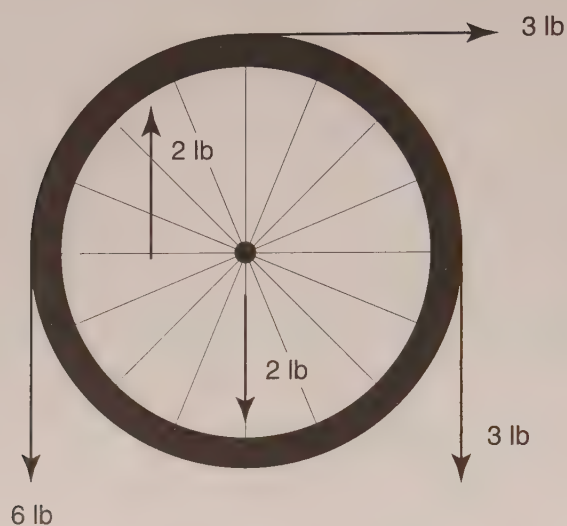
If a tangential force F is applied a distance r from the axis of rotation of an object, then the torque τ is given by $\tau = F \times r$. In other words, torque is the tangential force being applied times the distance from the axis of rotation. The following picture is an irregular object that is free to rotate about an axis which is perpendicular to the page. Five forces, all with the same magnitude, are acting on the object as shown.



Rank the forces in terms of how much torque they are exerting on the object. The strongest torque would be entered in row 1 and the weakest in row 5.

TORQUE	FORCE
1	
2	
3	
4	
5	

The following picture depicts a bicycle wheel with a variety of forces acting on it. Will the bicycle wheel rotate clockwise or counterclockwise as a result of these forces? Explain your reasoning.



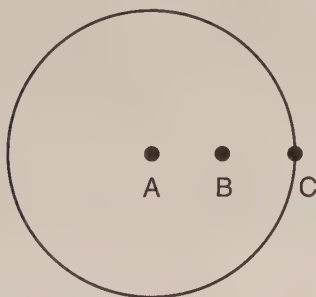
Activity**7.4****Moment of Inertia**

Mass is a measure of how much a body will resist changes in linear motion. More mass means it is harder to accelerate that body. *Moment of inertia* is a measure of how much a body will resist changes in rotational motion. Consider a body that is at rest. If it has a large moment of inertia, a large torque will be required to produce a given rate of change in angular speed. If it has a small moment of inertia, less torque is required to produce the same change.

The moment of inertia of a body depends on the mass of the body *and* distribution of mass about the axis of rotation. In general, the further the mass is away from the axis, the higher the moment of inertia.

In the following exercises you will be given a two-dimensional shape. Imagine rotating that shape about the various axes indicated. (Imagine that the axes are perpendicular to the page and you rotate the shapes clockwise or counterclockwise as viewed from above.)

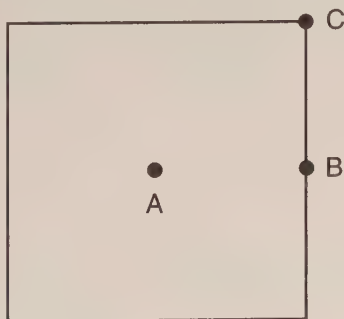
1.



About which axis will the moment of inertia be the greatest? C

About which axis will the moment of inertia be the least? A

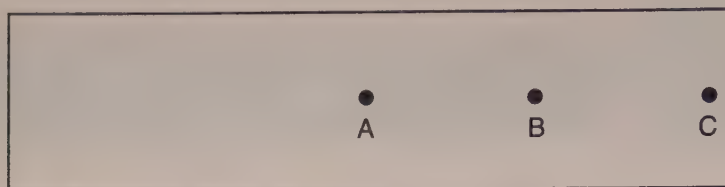
2.



About which axis will the moment of inertia be the greatest? C

About which axis will the moment of inertia be the least? A

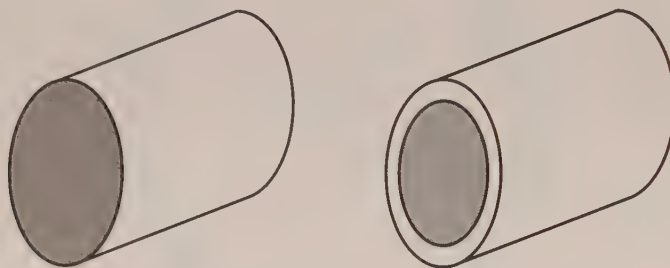
3.



About which axis will the moment of inertia be the greatest? C

About which axis will the moment of inertia be the least? A

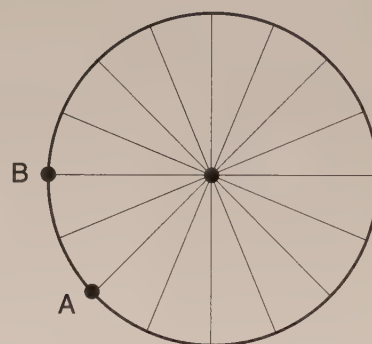
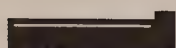
Two cylinders have the same dimensions (length and diameter) and the same mass. However, one is hollow and the other is solid.



If these two cylinders were released simultaneously at the top of an inclined plane, which one would win a race to the bottom? Explain.

Activity**7.5****Angular Momentum**

Consider a bicycle wheel that is free to rotate. A gun that fires wads of putty at high speed is positioned as shown. When the putty hits the tire, it sticks.



Suppose the tire is initially not rotating.

1. What happens when a wad of putty is fired from and sticks at location A?

2. What happens when a wad of putty is fired and sticks at location B?

3. In which of the above cases does the angular momentum of the wheel change? Does it increase or decrease?

4. A torque is required to change the angular momentum of a system (in this case the wheel). In the case where the angular momentum of the wheel changes, what is the force that creates the torque?

Now suppose that the wheel is initially rotating clockwise.

5. What happens to the moment of inertia of the wheel when a wad of putty sticks to the rim: does it increase, decrease, or stay the same?

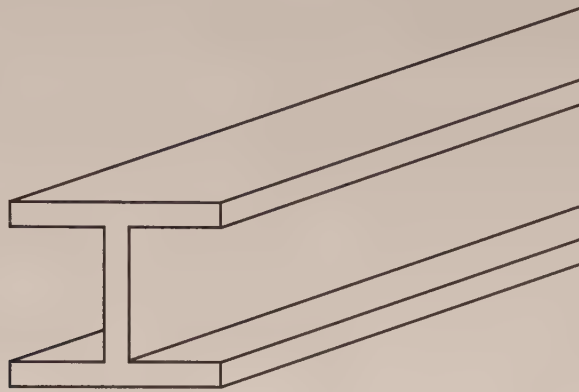
6. With the wheel rotating, what happens to the wheel if the putty is fired and it sticks at B?

7. Explain your answer to number 6 in terms of conservation of angular momentum.

Activity**8.1****Work and Power**

In this activity you will estimate the power of a crane used to lift steel beams to the top of a tall building. A typical steel beam used in the construction of large buildings has a mass of 1000kg. (1000kg is equivalent to 2200 pounds.)

$$m = 1000 \text{ kg}$$

**MAKING ESTIMATES**

Estimate the height of a tall building, in meters. 60 m

Estimate the time it should take the crane to lift the beam to the top of the building, in seconds.

60 s

WEIGHT OF THE BEAM

The weight of an object is equal to its mass times the acceleration of gravity. For simplicity, let the acceleration of gravity be 10 m/s^2 . Calculate the weight of the beam. Your answer will be in Newtons.

$$g = 9.8 \text{ m/s}^2$$

$$\text{Weight} = m \cdot g$$

$$= 1000 \text{ kg} \cdot 9.8 \text{ m/s}^2$$

$$= 9800 \text{ N}$$

WORK DONE

Work equals force times distance. If the force is in Newtons and the distance is in meters, the calculated work will be in Joules. Calculate the work done by the crane in lifting the beam.

$$\begin{aligned} \text{work} &= (\text{force by crane on beam}) (\text{height}) \\ W &= \text{weight} \cdot \text{height} = (9800)(60) \\ &= 588,000 \text{ J} \end{aligned}$$

POWER

Power equals work divided by time. With work in Joules and time in seconds, the calculated power will be in Watts. Calculate the power of the crane.

$$P = \frac{\text{WORK}}{t} = \frac{588,000 \text{ J}}{60} = 9,800 \text{ watts}$$

How many 100 Watt light bulbs need to be lit to equal the power of the crane?

One horsepower is equal to approximately 1000 Watts. What is the power of the crane in horsepower?

Compare the power of the crane to the maximum horsepower of a typical automobile. Are you surprised by your results?

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If you wanted to lift the same beams in $1/2$ the time, what power motor would you require?

On scrap paper, repeat the calculation of the horsepower of the crane using the following numbers: 100 meter height, 100 second lift time. What is your result? _____

Briefly discuss the reasons for any differences in the two results.

Activity**8.2****Energy and Power**

Kinetic energy is given by the formula $KE = 1/2mv^2$. If the mass is in kilograms and the velocity is in meters per second, then the kinetic energy is in *joules*. Thus, a 2 kilogram mass moving at 1 meter per second has a kinetic energy of one joule. ($KE = \frac{1}{2} (2)(1^2) = 1$ joule) It is useful to recall that one kilogram is approximately equivalent to two pounds and that one meter per second is approximately equal to two miles per hour.

In the following questions you will be asked to *estimate* the kinetic energy of various objects moving at various speeds. Be sure to state the mass and the speed that you used in your calculations.

1. Estimate the kinetic energy of a large SUV speeding down the highway.
2. Estimate the kinetic energy of a mosquito buzzing around your room.

3. Estimate the kinetic energy of a sprinter running a world record 100 meter dash.

Recall that 1 Watt is equal to one joule per second. 100 Watts is equal to 100 joules per second.

4. How long would it take a 100 Watt power source to create the energy of the SUV?

5. How long would it take a 100 Watt power source to create the energy of the mosquito?

6. How long would it take a 100 Watt power source to create the energy of the sprinter?
7. Gravitational potential energy is given by the formula $PE = mgh$. About how much gravitational potential energy would you gain by climbing Mt. Everest? (Assume you start your journey from sea level.)
8. How long would it take a 100 Watt power source to lift you to the top of Mt. Everest?

Activity**8.3****Energy and Pennies**

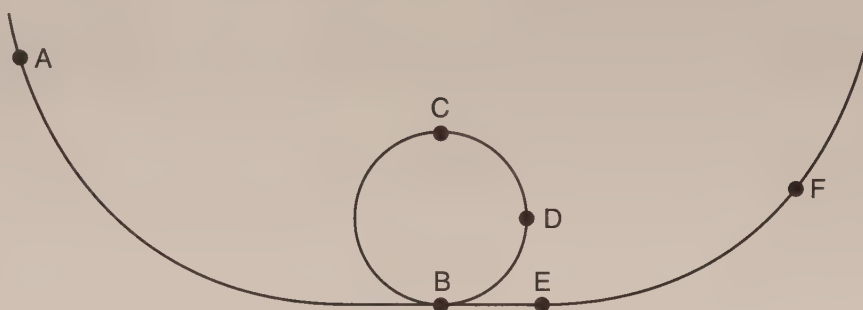
We've all heard the story: If you drop a penny off the top of the Empire State Building, the impact will create an eight inch deep hole in the concrete sidewalk. Other people will tell you that it will surely kill anyone that happens to get in its way. Are these just urban myths, or is there any truth to these stories? Surely if these stories are true, we don't want to be walking near tall buildings.

- A. Approximately how tall, in meters, is the Empire State Building? _____
- B. What is the approximate mass of a penny in grams? Convert this to kilograms.
- C. How much gravitational potential energy does a penny gain when it travels to the top of the Empire State Building?
- D. Suppose you drop the penny off the top of the Empire State Building and it falls to the road below. Neglecting frictional losses (air drag), what is its kinetic energy just before it hits the road?

- E. Neglecting frictional losses, how fast would it be moving just before it hits the road? Convert this speed to miles per hour.
- F. Do you think this is fast enough to dig an eight inch hole in the concrete? _____
- G. What is the mass of a baseball?
- H. How fast would a baseball have to be moving in order to have the kinetic energy calculated in D?
- I. Would the baseball in H hurt you if it hit you on the arm? _____
- J. Do you think air resistance would play a significant role in a realistic analysis of this problem, or is it acceptable to neglect air resistance? Explain.

Activity 8.4**Conservation of Energy**

Consider the simple roller coaster with a single loop-de-loop. A single car starts at A from rest. Neglect any frictional losses.



1. Rank the locations indicated on the diagram from highest gravitational potential energy to lowest. If there is a tie between two letters, list those two alphabetically.

2. There are three locations where there is no work being done on the car by gravity. What are they?

3. True or False

_____ The acceleration is the same everywhere.

_____ The total energy is the same everywhere.

_____ The speed is the same everywhere.

4. True or False

_____ The kinetic energy is always increasing.

_____ The acceleration of the car is zero at E.

_____ Gravity is doing work everywhere.

Activity**9.1****Avogadro's Principle**

Avogadro's Principle states that *equal volumes of a gas at the same temperature and pressure must contain the same number of molecules*. In this activity we will investigate the ramifications of this principle by analyzing some familiar chemicals.

Ammonia is a very toxic and reactive substance. The molecules of ammonia consist of hydrogen and nitrogen atoms. Do some research and find the chemical formula for ammonia.



Suppose you have a certain amount of ammonia, and you separate the nitrogen and the hydrogen atoms. Nitrogen atoms combine to form gaseous N_2 and hydrogen atoms form gaseous H_2 . If the hydrogen gas occupies a volume of six liters, what volume of nitrogen gas is produced?

Which gas has more mass? Explain your reasoning.

Now suppose you have two one gallon containers. One contains water vapor, and the other contains methane gas. The gases are at the same temperature and pressure. Compare the number of molecules in each container.

What is the chemical formula for methane? _____

Which gas has a greater mass? _____

A HYPOTHETICAL EXPERIMENT

You are given an unknown liquid and are asked to determine what atoms the liquid is made of, and the relative masses of the atoms. You separate the liquid molecules and find that you have formed two gases. One gas occupies a volume of three liters and consists of X_2 molecules. The other gas occupies a volume of one liter and consists of Y_2 molecules. The mass of the Y gas is three times the mass of the X gas.

Which of the following could be the chemical formula of the liquid molecules?

- a. X_2Y_2
- b. XY_2
- c. X_6Y_2
- d. X_2Y_6
- e. X_3Y_2

What is the relative mass of X and Y atoms?

Activity 10.1**Density**

Density is a measure of the amount of matter packed into a given volume. Something with lots of mass but a small volume is denser than something that has the same mass but a larger volume. In this activity you will explore the concept of density by approximating the density of an automobile and measuring the density of a book.

For this activity you will need a ruler, an ordinary bathroom scale, and a calculator. Some useful approximate conversions are:

1 kilogram is approximately equivalent to 2.2 pounds.

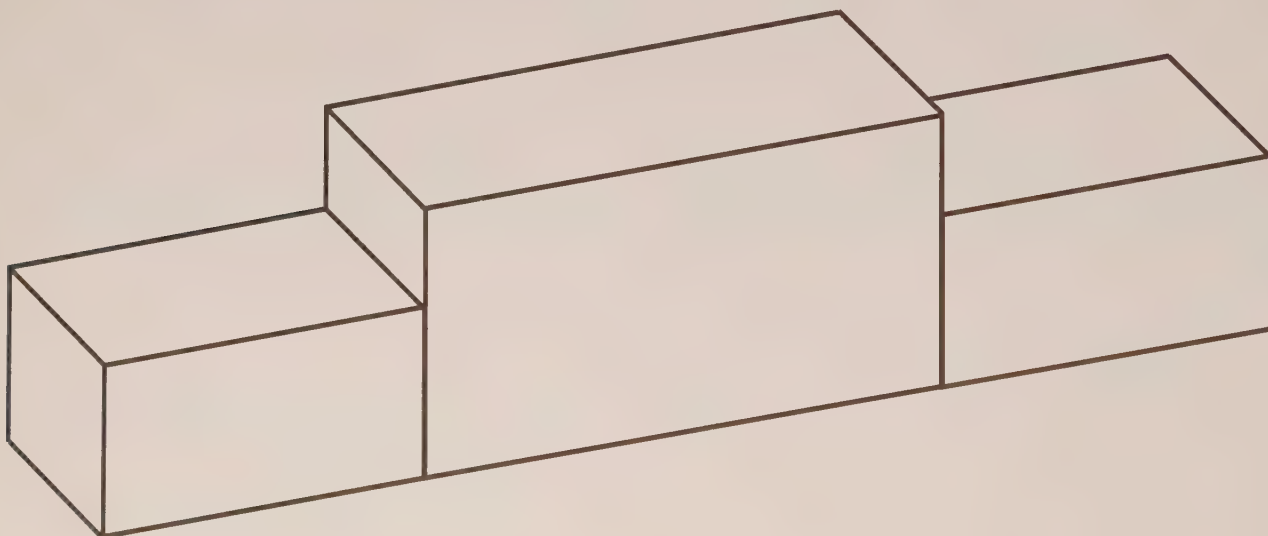
1 inch is approximately equal to 2.5 centimeters.

THE DENSITY OF AN AUTOMOBILE

What is the density of a typical automobile? To answer this question, you will need to find the approximate mass of an automobile. The mass of an automobile is sometimes printed on the registration certificate or can be found in the owner's manual. If you have no access to a real automobile, then do some research on the internet.

What is the approximate mass of an automobile in kilograms? _____

Now you need to approximate the volume of the automobile. For sake of simplicity, imagine that the automobile has the following shape:



Thus, its volume is simply the sum of the volume of the three boxes. Draw the dimensions of the boxes on the diagram. What is the volume of the automobile in cubic meters? Show your calculations.

Is the density of the automobile greater or less than steel? _____

Does your result make sense? Explain.

DENSITY OF A BOOK

Find a large and heavy book. Weigh it on your scale. What is its mass in kilograms?

Measure the length, width, and height of the book. What is its volume in cubic meters?

Calculate the density of the book.

Name _____ Date _____ Class _____

Since paper is made from wood, you may expect that the density of a book would be similar to the density of wood. Is the book more or less dense than wood? _____

If there is a difference, can you think of any reasons that may explain the difference?

Activity 10.3**Archimedes' Principle**

Any object immersed (fully or partially) in a fluid is subject to a buoyant force. In this activity we will explore the nature of the buoyant force and the rule that allows us to calculate the buoyant force, Archimedes' Principle.

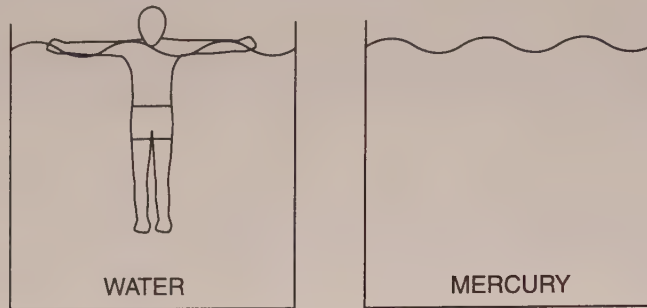
The figure depicts an irregularly shaped object completely immersed in water. The water is pushing in on the object from all sides. At each x in the figure, draw an arrow that represents the force due to the water pressure. The higher the pressure, the longer the arrow.



The cumulative effect of the water pushing in from all sides results in a buoyant force that pushes upward. How can you be sure that the buoyant force always pushes upwards?

For an irregularly shaped object, such as the one in the figure, it seems prohibitively complicated to calculate the buoyant force. After all, the water is pushing in from all sides, at all different depths, in all different directions! Thankfully, there once was a man named Archimedes who found that *the upward force exerted on an object immersed in a fluid is equal to the weight of the fluid that the object displaces.*

The figure below shows two tanks that contain fluid. On the left is a tank of water with a person floating in the water. On the right is a tank filled with mercury.



If the person in the water weighs 160 pounds, what is the weight of water that he is displacing?

Convert this weight to kilograms. _____

Since he is almost completely immersed, his volume is about equal to the volume of water displaced. What is the volume of water displaced, in cubic meters?

What is the volume of 160 pounds of mercury?

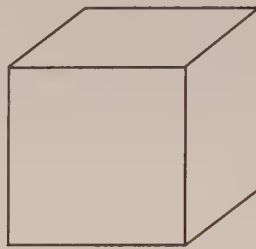
Suppose he steps out of the water and into the tank of mercury. Draw a stick figure of his body as it would look if he were floating in the mercury. What is the strength of the buoyant force when he is floating in the mercury?

Name _____ Date _____ Class _____

A toy boat sails from a pool of water into a pool of alcohol. Does the boat float higher or lower in the alcohol? Does the buoyant force change? Explain.

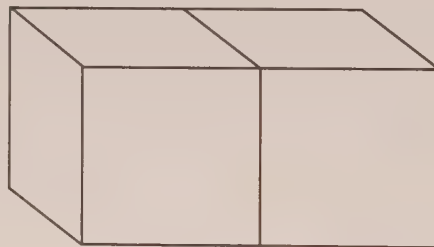
Activity 10.5**Heating a House of Cubes**

In this activity we are going to investigate the laws of scaling and how they are related to real life situations like heating a house. For simplicity, let's assume we have a cubical house. Let its volume be equal to 1 and each face of the cube has an area of 1. Thus the total exposed surface area of the house is 6. (We will assume that the floor is an exposed surface.)

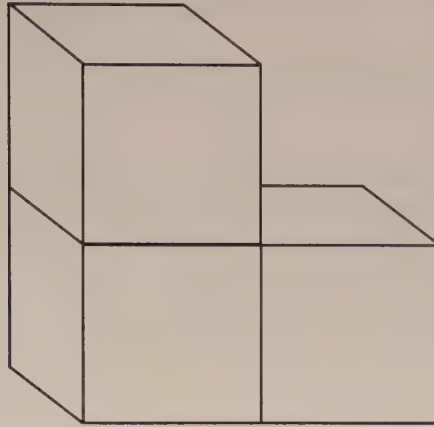


What is the exposed surface area to volume ratio of our cubical house? (Divide the total surface area by the volume.) _____

Suppose we connect two of our cubical houses together to form a duplex, as shown. What is the exposed surface area to volume ratio of the duplex? _____



Now suppose that a third house is connected, as shown. What is the exposed surface area to volume ratio now? _____



Does it make any difference where the third unit is placed? _____

Based on your results, can you explain why it is more efficient (from an energy efficiency standpoint) to live in an apartment building rather than a single family home?

Construct (draw) the most efficient four unit apartment building you can devise with four cubic units. What is its exposed surface area to volume ratio? _____

Name _____ Date _____ Class _____

Construct (draw) the least efficient four unit apartment building you can devise with four cubic units. What is its exposed surface area to volume ratio? _____

Activity 11.1**The Celsius Scale**

Unless you're from the United States, you probably don't need to do this activity. This activity is designed to help familiarize you with the Celsius temperature scale. First, you will be asked to convert some familiar temperatures from Fahrenheit to Celsius. Show your calculations please!

What is body temperature in the Celsius scale?

What is the temperature on a hot day in the Celsius scale?

What is the temperature on a cold day in the Celsius scale?

Name _____ Date _____ Class _____

To what temperature do you cook a turkey in the Celsius scale?

What is the temperature of a frozen lake on the Celsius scale?

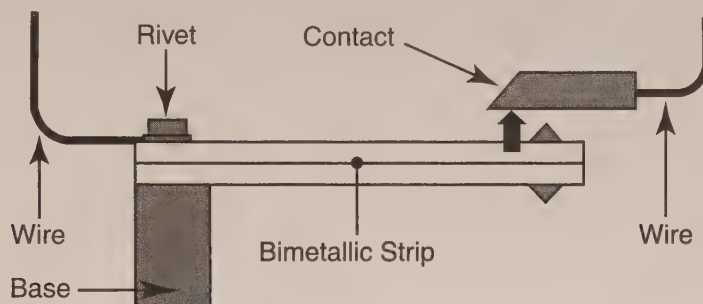
Activity 11.2

Applications of Thermal Expansion

The fact that things expand when they are heated has many important ramifications in our everyday life. Indeed, many products we use rely on this fact.

THE BIMETALLIC STRIP

Consider the device shown in the picture. The heart of the device is the bimetallic strip, which is simply two different pieces of metal glued together. An electrical connection can be made if the bimetallic strip bends upward and touches the contact.



Suppose we want to use this device as a heat detector. When the temperature gets too high, the strip will bend upward and make contact. Which piece of metal making up the strip should have the higher coefficient of thermal expansion? Explain.

NUTS AND BOLTS

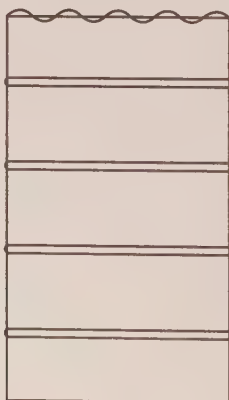
The diagram shows an ordinary hexagonal nut. What happens to the area of the hole if the temperature increases?



Suppose you screwed a bolt into the nut and the thermal expansion coefficient of the nut was higher than that of the bolt. If the temperature decreased, would the nut be more difficult or easier to remove? Explain.

LIQUID IN A METAL CONTAINER

A steel drum is holding water. The water is filled to the brim. If the temperature increases, water spills over the side. What does that tell you about the relative expansion coefficients of water versus steel? (2 lines)



HOW SMALL WILL THINGS GET?

Your friend says that since things get smaller when temperature decreases, they will eventually disappear at low enough temperatures. Is she right? Back up your answer.

Activity**11.3****Calories**

Heat is often measured in *calories*, which is the amount of heat necessary to raise the temperature of 1 gram of water by 1 degree Celsius. The familiar food Calorie (with a capital C) is equal to 1000 calories. So one Calorie is equal to the amount of heat (energy) necessary to raise 1000 grams, or 1 kilogram, of water by 1 degree Celsius.

1. Let's start this activity by answering a few preliminary questions.

- a. What is your mass in kilograms? _____
- b. Convert normal body temperature (98.6 degrees Fahrenheit) to degrees Celsius.
- c. A dangerously high fever is associated with a body temperature of about 105 degrees Fahrenheit. What is this temperature in degrees Celsius?

Let's assume that all of the food that goes into your body is converted into heat energy during digestion. (In reality, only some of the energy liberated during digestion is turned into heat.) Let's also assume your body is made of pure water (not a bad rough approximation).

2. How many Calories of food would you have to ingest in order for your body temperature to become dangerously high?

3. What is the Calorie content of a typical candy bar? How much of that candy bar would be sufficient to raise your body temperature to dangerous levels?

Let's talk about dieting. It seems that everyone knows someone who is trying to lose weight by dieting. One pound of fat stores about 3500 Calories of energy. Thus if your body uses 3500 Calories of energy, you will lose a pound of fat (provided you are maintaining a balanced diet at the time). Your body uses energy when you drink cold water. Why? Because the cold water must be heated to normal temperature by your body. So it's possible (in principle) to lose weight by drinking water.

4. If you drank one liter (1 kilogram) of ice water that was initially at zero Celsius, how much would its temperature increase inside your body? _____
5. How many Calories of energy are necessary to raise the temperature of one liter of water by this amount? _____
6. How many liters of ice water would you need to drink in order to lose a pound?

7. Is this a reasonable way to go about losing weight? Explain.

Activity 11.4**Heat and Internal Energy**

The everyday meaning of "heat" is often different from the precise scientific meaning. Heat is the flow of internal energy from one body to another. Review chapter 11 if you need a refresher on this material.

TRUE OR FALSE

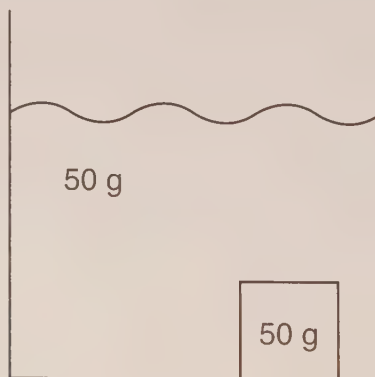
- _____ An object with a higher temperature always has more internal energy than another object with a lower temperature.
- _____ If an object's temperature increases, so does its internal energy.
- _____ The only way to increase the temperature of a glass of water is to transfer heat to the water from an object at a higher temperature.

The specific heat of a material is defined as the quantity of heat required to raise the temperature of one gram of that substance by 1°C .

TRUE OR FALSE

- _____ Substances with high specific heats tend to cool down faster than substances with low specific heats.
- _____ If water had a lower specific heat, it would take less time to heat a cup of water from 10°C to 50°C .
- _____ You cannot cool an object with a high specific heat to less than 0°C .

Suppose that 500 grams a solid substance, with an initial temperature of 100°C , is dropped into 500 grams of water with an initial temperature of 0°C . Assume that the liquid and solid only exchange heat with each other (the system is thermally insulated).



Name _____ Date _____ Class _____

The temperature of the solid will _____. Heat flows from the _____ to the _____.

Is it possible to determine the final temperature of the mixture? If so, what is the final temperature? If not, what other information would be needed?

A piece of paper and a piece of aluminum foil have the same thickness and are placed in a 400°F oven. After an hour, you open the oven and take out each with your bare hands. The aluminum does not burn your hand, but the paper does.

Is the temperature of the paper likely different than the temperature of the aluminum foil? Explain.

Is the specific heat of paper likely different than the specific heat of aluminum? Explain.

If a solid block of aluminum were in the same oven, you would burn yourself when taking it out of the oven with bare hands. Why?

Activity 11.5**Heat Transfer*****RADIANT ENERGY***

When it's hot and sunny outside, many people will seek the shade of a tree to cool down. The sun's rays constitute a form of heat transfer called radiation. When you get into a shady area, this radiation is no longer warming your body.



1. Of course it feels cooler under a shady tree, but is the air temperature much cooler under the tree? Explain your reasoning.

2. Suppose that while sitting outside on a sunny day, your body absorbs 200 Joules of radiant energy from the Sun each second. In order to maintain a constant body temperature, you must be losing 200 joules of heat per second. Explain, in detail, how your body is losing heat through conduction, radiation, and convection.

WIND CHILL

3. On a warm day, a breeze will help keep you cool. This is called the wind chill effect. How does it work?

4. Would the wind chill effect work if the air temperature were greater than your body temperature? Explain.

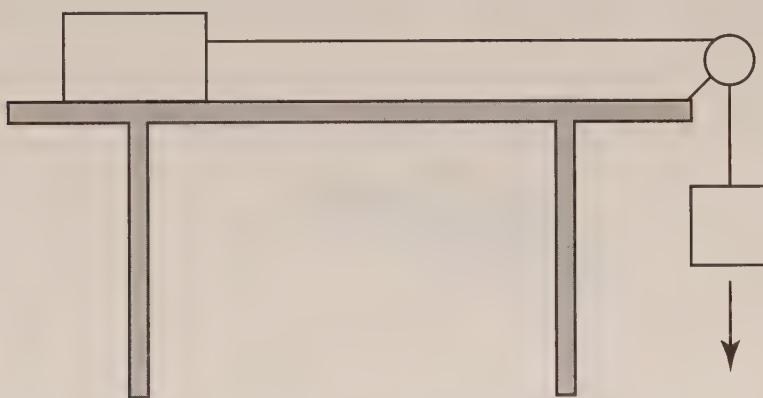
INSULATION

5. The reason a foam cooler is able to keep beverages and food cool for so long is the low thermal conductivity of its walls. Would a foam cooler be equally effective at keeping hot beverages and food warm? Explain.

Activity 12.1**Interchangeability of Energy**

Chapter 12 discusses various forms of energy and the fact that they can be transformed into one another. In the following situations, follow the energy transformations, stating what form of energy is being converted to what other forms of energy. Choose from the following list: *chemical potential energy, gravitational potential energy, elastic potential energy, thermal energy, wave energy, kinetic energy*.

1. A block of wood hangs from a table and falls to the ground, dragging another block across the table.

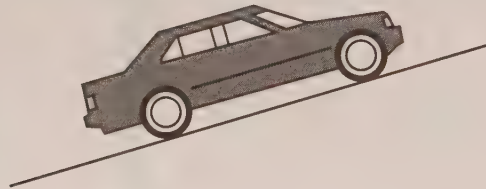


2. A rock is dropped into a small pond and creates a wave that breaks on the shores of the pond.

3. An archer draws his bow and fires an arrow towards the top of a tall tree. The arrow sticks into the tree.

4. A stick of dynamite explodes, creating a fireball and a large sound.

5. A woman steps on the gas to power her car up a steep hill.



6. The sun sends out radiation that heats the water in your solar powered house.

Activity 12.2

The First Law of Thermodynamics

The first law of thermodynamics states that *in a closed system, the change in internal energy equals the heat added to the system minus the work done by the system.*

In the following situations there is an increase in the internal energy of the system. State whether the change in internal energy is a result of work done by the system or heat added to the system.

The internal energy of water increases when it is put on a hot stove. _____

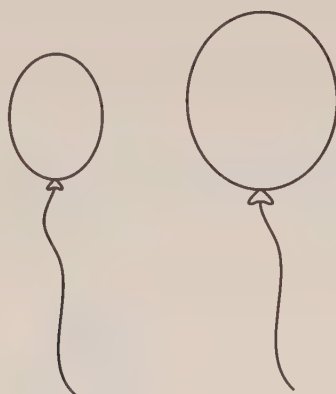
The internal energy of your hands increases when you rub them together. _____

The internal energy of the air in your bicycle tires increases when you sit on your bicycle.

The internal energy of the water in your swimming pool increases as spring becomes summer.

THINKING MORE ABOUT WORK

Suppose an ordinary party balloon is moved from a cold room to a warm room. Heat is conducted through the rubber balloon and the temperature of the gas inside increases. The balloon expands and the temperature of the gas in the balloon increases.



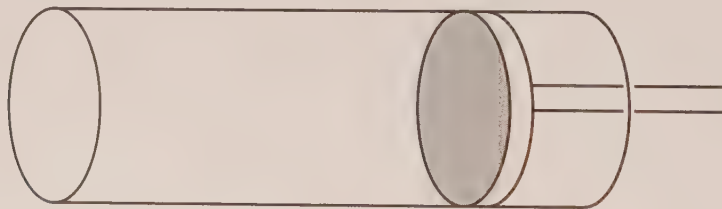
1. The balloon did work in the process of expanding. We learned in previous chapters that work is a force times a distance. What is the force? What is the distance?

2. If the heat added was 500 joules, and the change in internal energy was 900 joules, how much work did the balloon do?
3. Suppose the balloon had been rigid, so it didn't expand during the heating process. Would the change in internal energy be greater or less than in the case with the expanding balloon?

4. If the balloon were rigid, would the temperature increase be greater or less than in the case with the expanding balloon?

5. How much work did the balloon do in this case?

Now consider a piston and cylinder that contains air. Let's think about what happens when the piston is pushed into the cylinder so the gas is compressed. Suppose the force pushing on the piston is approximately 300 Newtons and the piston moves 1 centimeter (0.01 m).



6. Calculate the work done.

7. If 2 joules of heat was lost from the cylinder during the compression, what was the change in internal energy?

Activity 13.1

The Second Law of Thermodynamics and Perpetual Motion

Chapter 13 presents three different statements of the second law of thermodynamics. They are (1) *heat does not spontaneously flow from a cold body to a hot body*; (2) *you cannot construct an engine that does nothing but convert heat completely into useful work*; and (3) *every isolated system becomes more disordered with time*.

1. A refrigerator causes heat to flow from a cold beverage to the warm air outside. Why doesn't this contradict (1)?

2. The heat generated in the cylinder of your car engine is converted into work as your car is accelerated up a hill. Why doesn't this contradict (2)?

3. After cleaning up your room, it seems more ordered. Why doesn't this contradict (3)?

In watching a movie of each of the following situations, could you determine whether or not the movie was being run in reverse? Yes or no?

A ball flies through the air _____

An ice cube melting _____

An apple falling towards the ground _____

An oil slick spreading on the water _____

A croquet ball rolls to a stop on a grass court _____

A perpetual motion machine is sometimes referred to as any device that violates the second law of thermodynamics. Consider the following perpetual motion machines and explain why they don't work. You may want to do a little research if you can't figure out the trick.

THE BHASHKARA MACHINE



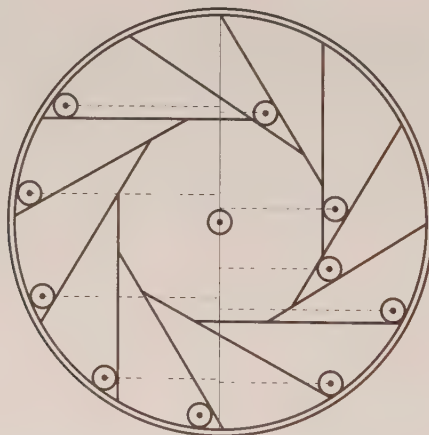
This is a wheel with containers of mercury around its rim. As the wheel turns, the mercury is supposed to move within the containers in such a way that the wheel would always be heavier on one side of the axle. How come this machine does not work?

SELF FLOWING FLASK



How come this "self flowing flask" does not continually circulate water?

THE OVERBALANCING WHEEL



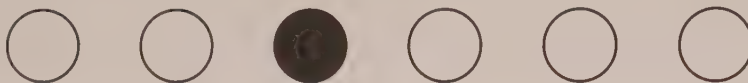
Name _____ Date _____ Class _____

The rolling balls are supposed to pull down on the left more than they pull down on the right, causing a perpetual counterclockwise rotation of the wheel. How come this ancient design does not work?

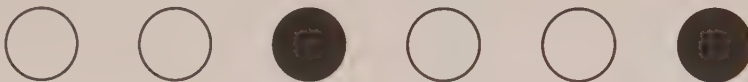
Activity 13.2**Entropy and Probability**

Entropy and probability are intimately related. In this activity we will look at the relationship between the number of different arrangements of a system (the disorder) and the probability that the system will be in one particular state. You will need a calculator for this activity. Review chapter 13 as necessary.

1. How many different ways can five white balls and one black ball be arranged? (balls of the same color are indistinguishable) _____



2. How many different ways can four white balls and two black balls be arranged? _____



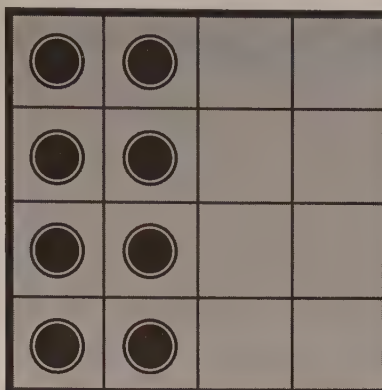
3. How many different ways can three white balls and three black balls be arranged? _____



4. What is the probability that a random arrangement of the balls in number 3 will yield the combination shown below? _____



Now consider a 4x4 checkerboard with eight black checkers.



5. How many different ways can the eight checkers be arranged on this checkerboard?

6. What is the probability that placing the checkers on the board randomly will yield an "ordered" state where all of the checkers are on the left half of the board?

7. How many different ways can the checkers be arranged so that four are on the left half of the board and four are on the right half?

8. What is the probability that placing the checkers on the board randomly will yield a state where four checkers are on the left half of the board and four are on the right half?

Name _____ Date _____ Class _____

9. How do your answers to 5-8 relate to entropy and the second law of thermodynamics?

Activity 13.3**Monte Carlo**

In chapter 13 you learned that systems tend to become disordered as time goes by. Thus, the likelihood of finding an ordered state in nature can be quite small. In this activity we will demonstrate this with a Monte Carlo Simulation. Generally speaking, a Monte Carlo Simulation is the use of a random number generator to simulate the behavior of a model.

The model we would like to simulate is a *random walk* in one dimension. Consider the following line of five X's. Place a marker on the middle X (a button or paper clip will work just fine). Now flip a coin. If you get heads, move the marker to the right, tails move it to the left. Keep flipping the coin until your marker lands on the left most X. If the coin is on the right most X and you flip heads, you don't move the coin, but it still counts as flip.



1. How many flips of the coin did it take before the marker reached the left most X?

2. Repeat the simulation. How many flips did it take this time? _____

Now look at the array of numbers on page 109. These numbers were generated randomly and range from 0 to 9. They will serve as a random number generator for our next simulation, just as flipping a coin serves as a random right-left generator. In order to generate a sequence of random numbers from 0-9, just start anywhere on the grid and work your way up-down or left-right.



Consider the 10 spaces numbered 0 to 9. Place five markers (coins will work well) on five different locations as follows:

- Pick a random number.
- Place a marker on that number if it is not already occupied.
- Repeat until all five markers are placed.

Now we will simulate the random walk as follows:

- Pick a random number.
- If that marker is occupied, flip a coin. Heads means a move to the right, tails means a move to the left.
- Move the marker right/left only if the space is unoccupied. Also a marker on space 9 cannot hop to the right and a marker on space 0 cannot hop to the left.
- Repeat this procedure until (1) all five markers are in spaces 0-4, or (2) you run out of random numbers.

3. What was the outcome of your simulation?

4. How is this simulation related to entropy and the second law of thermodynamics as discussed in chapter 13?

2 2 1 6 8 6 9 0 0 9 5 0 0 4 0 6 3 4 0 9 2 8 1 1 4 5 4 9 9 3
 6 1 2 4 1 1 3 7 0 7 3 4 7 8 6 1 2 4 8 1 4 0 3 6 4 6 1 9 7 0
 3 9 8 8 5 7 3 1 0 5 0 5 7 1 4 9 3 7 4 4 2 8 5 4 5 5 7 0 1 6
 4 6 0 3 4 7 5 2 3 3 1 6 4 7 4 5 4 4 7 2 8 8 5 4 9 0 6 8 9 8
 0 6 1 7 8 0 3 1 2 5 1 2 0 2 8 5 2 3 8 2 6 4 8 9 2 3 5 8 9 7
 2 8 9 7 9 7 9 2 9 9 6 0 6 9 0 2 0 1 0 0 2 6 6 0 8 3 2 3 8 7
 6 8 6 0 5 6 5 4 6 5 1 3 3 9 6 2 8 3 3 1 8 6 2 7 4 4 8 0 6 8
 9 3 5 4 8 5 4 2 8 0 0 6 0 1 8 7 5 5 1 0 6 0 8 7 7 9 5 3 6 4
 8 7 2 8 1 0 6 0 9 3 9 7 8 7 7 0 3 2 0 8 0 9 3 3 3 9 3 0 4 7
 5 4 5 4 9 8 6 5 5 9 5 9 0 9 3 3 1 2 2 8 6 8 1 6 1 2 5 0 7 9
 6 6 2 4 8 5 1 6 3 8 0 5 7 3 6 1 5 4 0 4 6 0 4 0 7 1 1 0 0 5
 6 8 6 0 6 0 4 4 4 4 0 7 7 7 7 7 3 1 5 6 6 5 5 6 2 8 8 0 8 6
 4 2 1 3 0 3 6 1 6 6 9 1 7 7 5 9 2 0 8 0 3 5 9 0 8 9 9 7 8 7
 1 7 2 7 9 3 5 8 1 7 1 8 1 1 0 9 0 7 5 7 5 3 4 7 4 7 6 1 7 6
 6 3 4 7 9 4 5 8 4 1 9 9 1 2 0 0 1 5 7 3 9 1 4 0 9 4 4 6 1 3
 3 2 5 4 6 9 8 1 0 7 6 6 8 5 1 7 6 1 5 6 1 3 4 8 0 5 8 3 7 6
 2 3 4 6 5 3 9 0 1 3 4 7 2 8 4 6 2 0 3 9 4 0 6 6 9 8 2 7 4 3
 0 6 5 3 3 2 5 3 7 4 2 0 9 8 8 2 0 8 2 3 0 6 1 1 6 7 6 8 1 1
 7 6 4 0 2 8 6 3 4 0 1 0 9 1 6 6 0 8 0 1 5 1 8 6 5 4 7 2 3 3
 7 2 7 0 3 2 2 9 4 3 2 7 6 3 6 0 9 9 5 5 8 2 6 7 4 5 9 0 9 7
 1 5 6 2 8 8 6 2 9 4 3 9 9 0 3 9 8 4 2 5 4 2 7 5 3 0 5 3 4 3
 5 3 1 0 7 0 2 0 0 3 6 6 2 1 6 5 6 6 1 0 5 6 0 6 4 2 7 4 2 7
 0 6 1 4 2 2 4 8 1 0 9 4 1 2 2 7 9 6 9 4 1 9 1 5 9 2 3 9 8 7
 6 8 8 1 6 7 8 3 0 1 4 5 5 1 8 1 5 6 1 8 5 7 5 1 2 8 2 1 2 4
 7 6 0 3 9 8 6 3 4 7 2 2 6 5 2 9 7 5 9 0 1 3 7 7 7 6 8 3 0 6
 5 1 3 9 9 5 7 1 7 4 9 0 2 2 0 8 6 0 9 2 0 0 4 1 3 5 1 5 4 5
 0 1 7 0 0 3 3 2 2 6 1 5 6 2 7 3 1 3 5 1 0 6 0 6 0 0 7 4 3 3
 0 3 6 7 9 4 0 9 9 6 1 8 5 4 7 2 0 6 3 1 5 2 2 9 6 8 6 0 2 3
 8 2 7 7 4 1 7 9 8 4 3 3 6 5 7 2 8 1 8 3 3 2 2 1 9 8 1 8 8 7
 3 9 4 9 1 5 0 0 3 6 3 1 1 5 8 4 2 5 6 0 8 5 5 6 2 9 9 8 5 3
 9 6 2 7 7 7 6 5 4 6 0 5 7 8 3 9 2 2 2 3 0 6 6 4 8 8 2 0 4 5
 3 9 0 8 9 9 3 4 5 9 3 4 3 6 2 3 6 0 4 9 8 5 1 4 8 1 5 6 7 7
 5 3 2 9 3 0 4 0 8 1 3 7 4 4 2 1 9 1 3 4 3 9 8 9 0 0 7 0 2 2
 7 9 2 1 3 7 7 2 1 5 5 1 8 2 2 2 5 2 8 2 6 4 2 6 6 6 1 2 0 6
 2 4 5 3 7 8 8 2 0 6 6 1 3 2 5 4 8 9 3 9 9 1 1 1 4 5 2 1 6 0
 5 1 3 4 7 4 3 9 1 5 5 2 3 4 2 1 3 7 8 6 5 9 9 5 6 5 8 9 3 0
 7 2 6 6 6 3 9 5 4 4 9 8 9 4 2 2 4 6 3 4 0 1 9 7 6 1 0 1 5 0
 4 4 1 9 3 9 3 1 8 1 7 2 1 0 3 6 4 5 2 0 0 7 6 8 0 6 9 1 1 2
 7 3 6 0 2 6 8 2 0 3 2 6 5 4 8 8 5 3 0 7 2 7 9 6 7 5 6 7 8 2
 9 8 0 6 0 9 4 4 5 9 3 6 2 2 0 6 8 0 6 0 6 7 4 4 3 4 7 9 1 0
 6 4 0 0 0 3 8 5 5 2 4 6 7 5 1 7 0 5 4 9 6 2 9 1 2 4 3 2 8 8
 5 6 0 8 6 4 9 9 6 0 2 8 3 5 1 8 9 3 7 2 7 7 3 0 6 7 7 0 2 4
 2 3 7 6 2 0 5 6 1 0 0 6 9 8 0 0 9 1 2 3 1 4 1 8 4 8 2 5 3 2
 1 2 9 4 9 5 9 3 2 8 8 2 1 3 2 5 2 0 2 0 7 7 5 7 3 5 7 8 7 3
 1 4 0 2 7 3 2 8 4 2 7 4 6 2 0 9 3 8 3 7 7 9 5 2 1 5 7 4 1 4
 6 9 7 5 7 3 9 7 9 9 7 9 1 4 7 4 4 4 2 4 2 3 1 6 0 9 7 0 8 7
 8 8 8 2 6 0 1 2 3 6 5 0 8 1 6 1 4 6 4 8 0 1 9 4 8 7 0 5 0 5
 6 4 3 1 8 8 6 3 3 9 6 5 1 6 3 5 0 8 2 4 8 5 9 9 7 9 3 4 6 6
 9 8 2 6 0 2 3 0 2 0 1 5 8 7 6 2 8 7 5 1 8 5 1 7 9 8 9 1 5 3
 5 4 6 3 2 8 4 7 6 7 7 5 0 3 7 8 1 8 7 0 0 4 8 3 3 9 8 5 8 7
 3 1 4 1 7 0 5 1 6 7 4 4 7 0 2 7 0 4 5 9 9 1 8 9 8 7 6 2 8 5
 5 7 8 1 4 6 9 6 2 9 5 2 6 6 6 5 0 1 2 7 6 0 3 9 2 7 1 1 0 1
 0 8 9 4 9 3 4 2 5 8 3 9 6 4 2 9 2 5 1 4 7 5 3 4 3 8 2 7 8 5
 4 7 7 4 2 9 1 1 1 6 8 1 2 5 3 3 4 4 6 7 9 2 1 2 1 6 7 4 0 8
 4 1 0 7 4 7 7 0 6 1 4 1 9 6 8 2 1 2 2 5 9 4 3 0 7 7 6 3 7 2
 8 3 5 8 3 5 7 2 6 8 1 5 6 3 4 4 0 3 9 4 8 3 7 9 0 9 2 1 6 0
 2 5 5 7 2 3 9 2 0 5 1 0 4 1 2 4 4 5 9 1 0 4 2 8 2 8 5 6 8 5
 2 0 4 6 9 5 3 0 3 2 0 9 3 8 3 7 3 9 3 7 2 5 9 0 7 1 4 9 9 6
 3 8 3 5 8 8 0 3 6 8 9 5 4 7 0 5 7 2 8 8 1 2 8 1 1 2 0 6 7 6
 2 6 1 2 1 3 9 5 1 7 4 6 4 7 4 1 9 2 7 2 6 6 9 6 8 3 9 1 1 9
 4 5 9 9 1 4 2 8 9 2 2 3 4 6 7 4 3 6 0 4 2 8 6 8 6 9 6 7 9 5
 1 2 4 2 0 9 1 0 5 4 3 1 9 5 5 7 5 5 5 4 8 6 3 0 0 4 5 3 0 0
 8 5 5 6 3 8 5 0 0 3 4 3 7 0 0 0 1 3 3 1 6 8 6 9 6 0 5 8 8 1
 2 4 6 3 2 2 8 4 5 8 8 1 5 2 1 0 3 0 8 5 9 5 9 6 3 7 6 7 3 8
 8 7 5 4 2 5 9 3 2 7 5 2 5 9 4 7 1 8 7 5 0 3 8 0 8 5 0 0 9 5
 9 9 3 0 6 0 5 4 9 4 2 7 4 2 5 0 2 3 3 3 7 9 4 6 5 6 8 9 2 0
 1 0 0 2 5 4 7 3 7 6 5 3 9 9 1 3 3 3 3 7 5 6 7 1 9 4 9 6 2 6
 6 3 8 4 6 6 7 9 4 9 9 1 1 2 0 5 9 0 0 9 9 0 2 4 4 3 5 1 4 8
 7 6 4 7 4 9 9 1 1 6 6 6 4 6 3 2 4 3 8 2 1 1 4 3 4 7 8 5 2 0

Activity 14.1**A Pendulum Experiment**

A simple pendulum is a system that executes simple harmonic motion. In this activity you will investigate the relationship between the period, frequency, and length of a simple pendulum. You will need some string, a ruler, a small mass that you can tie the string to, and a stopwatch or watch with a second hand. The mass should be heavy enough so that the pendulum swings back and forth freely for many cycles before stopping.

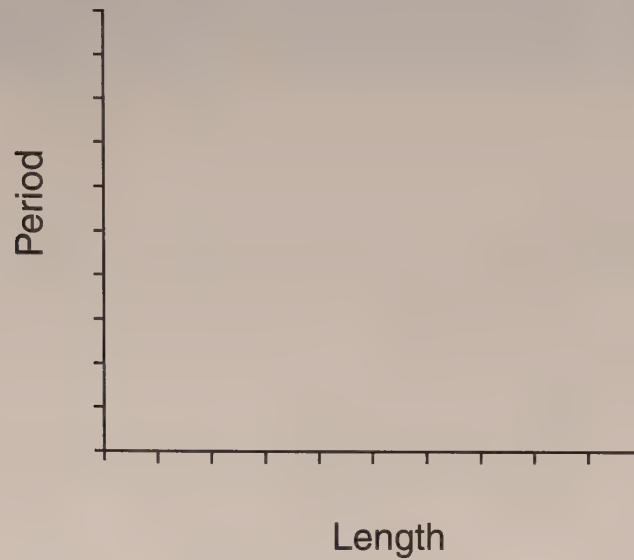
Describe the string you are using.

Describe the mass you are using.

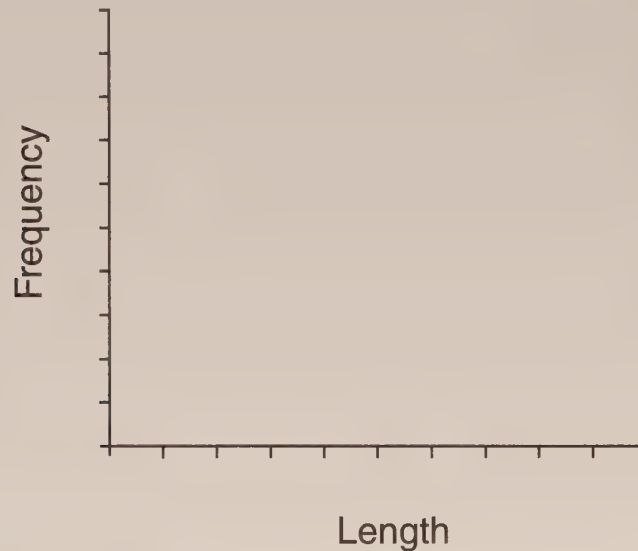
For five different lengths of string, measure the period and frequency of the pendulum. The best way to measure the period is to determine the time it takes the pendulum to swing back *and* forth 10 times. Divide this time by 10 to get the period. Fill in the table with your data. Be sure to include the units of your measurements.

LENGTH	PERIOD	FREQUENCY

Plot the period versus the length on the graph below.

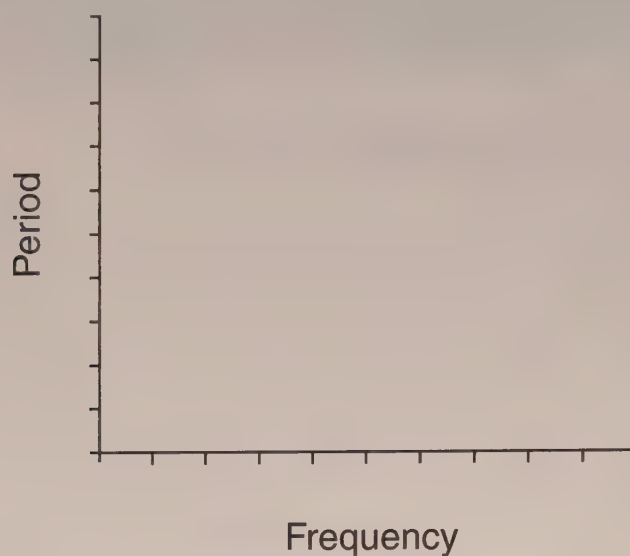


Plot the frequency versus length on the graph below.



Describe how the period and frequency of a pendulum are related to the length.

In the graph below, plot the period versus the frequency.



What kind of relationship is this?

Is there an equation in the book that confirms your conclusion? If so what is it?

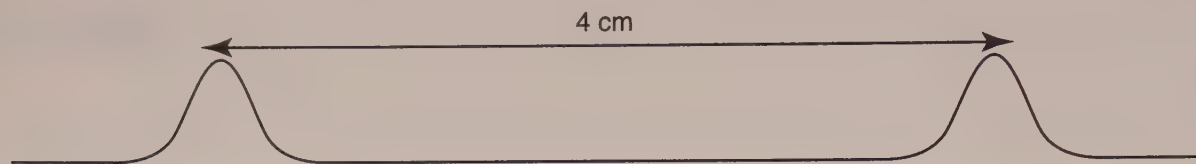
Activity 14.2**Waves**

Consider the following "snapshot" of a wave. It could be a water wave or a wave on a string. Use a ruler to measure the dimensions of this wave in centimeters.



1. What is its wavelength? _____
2. What is its amplitude? _____
3. If the wave is traveling at a speed of 3 cm/s, what is its period?
4. What is its frequency?

When two waves encounter each other, they *interfere*. The height of the resultant wave is simply the sum of the heights of the interfering waves. Consider the two wave pulses pictured below. They are traveling toward each other at a speed of one centimeter per second and their peaks are separated by a distance of 4 centimeters. Sketch the resultant wave 1, 2, 3, and 4 seconds later.



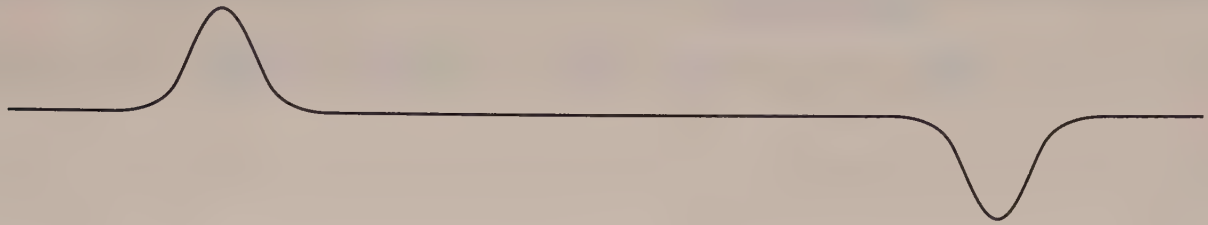
1s — — — — —

2s — — — — —

3s — — — — —

4s — — — — —

Consider the two wave pulses pictured below. They are traveling toward each other at a speed of one centimeter per second and their peaks are separated by a distance of 4 centimeters, except this time the right wave is inverted. Sketch the resultant wave 1, 2, 3, and 4 seconds later.



1s _____

2s _____

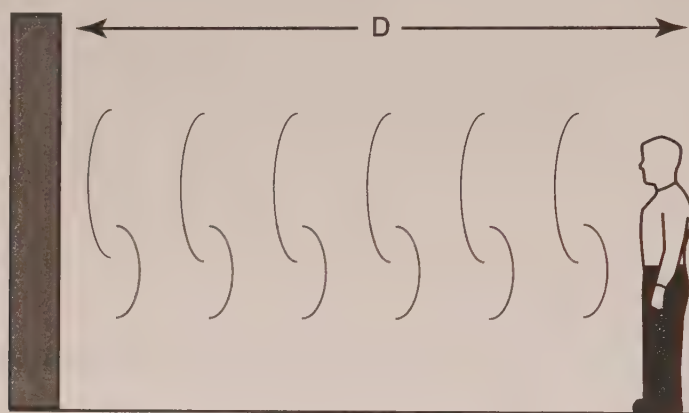
3s _____

4s _____

Activity**15.1****Measuring the Speed of Sound**

The speed of sound can be measured by doing the following simple experiment. You will need a stopwatch and as long a measuring tape as you can find and two blocks of wood to clap together. If blocks of wood are not available, anything that makes a sharp clapping sound will do. You will need a friend or classmate to help with the experiments.

Find a building that has a large, unobstructed outside wall. Stand a measured distance away, facing the wall. If the blocks are clapped together, an echo should be heard as the sound travels to the wall and is reflected back. The trick to the experiment is to synchronize the claps with the echoes so that you clap at precisely the time the echo from the previous clap reaches you. The time between claps is equal to the time it takes for the sound to travel to the building and back.



Find a location in front of the building and measure the distance to the building. What is the distance to the building? _____

Start clapping and get a feel for synchronizing the claps with the echoes. Once you get a feel for it, have a friend time 10 claps. The time between claps is this time divided by 10.

What is the time for 10 claps? _____

What is the time between consecutive claps? _____

Calculate the speed of sound. Show your work.

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How close is your answer to the speed of sound presented in chapter 15?

Think of several possible sources of error in this experiment and discuss how they may have affected your results.

Another way to measure the speed of sound would be the following: Two people stand far from each other on a flat, open space. One claps the blocks, the other starts a stopwatch when the blocks are clapped and stops it when the sound is heard. The speed of sound is the distance between the people divided by the time. Do this experiment.

What is the distance between the people? _____

What is the time? _____

Calculate the speed of sound. _____

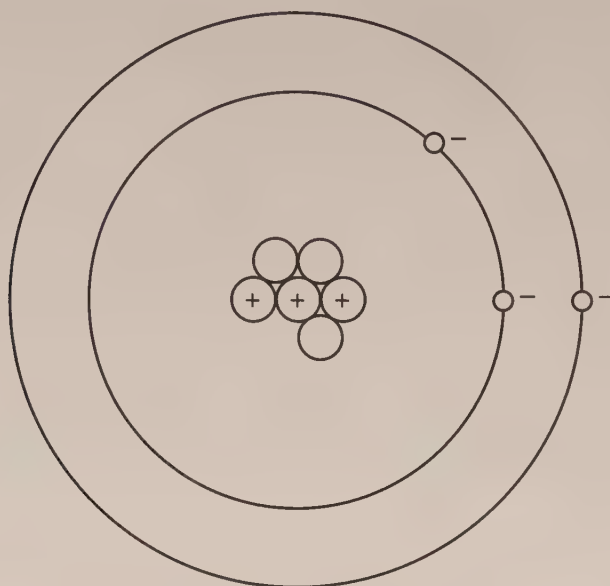
Think of several possible sources of error in this experiment and discuss how they may have affected your results.

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Compare the two methods. Which do you think gives a more accurate result? Why?

Activity 16.1**Positive and Negative Charge**

For the most part, the world is made up entirely of three elementary particles: electrons, protons, and neutrons. The nucleus of the atom contains protons and neutrons and electrons orbit the nucleus.



Neutrons have no electrical charge, protons have a positive charge, and electrons have a negative charge. Usually there is the same number of electrons and protons in matter, which deems it electrically neutral. Like charges repel and opposite charges attract.

In this activity we will experiment with static electricity. You will need several ordinary party balloons and some thread.

HAIRBALLOON

Blow up a balloon and rub it in your hair vigorously. Then hold it near your head. Describe what happens.

Explain what happened in terms of the movement of electric charge from the balloon to your hair or vice versa.

HANGING BALLOONS

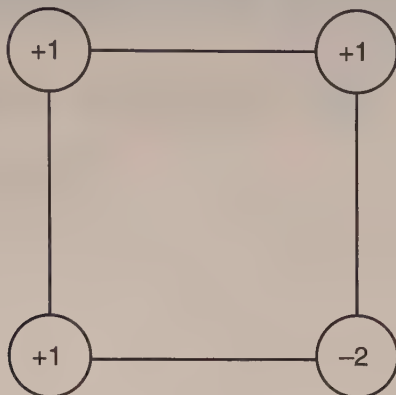
Now blow up two balloons, rub them in your hair, then hang them from threads.

Describe what happens.

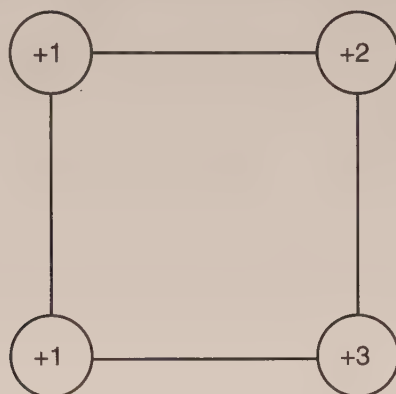
Do they repel or attract? Explain what happened in terms of electrical forces between the balloons.

The following charges reside on the corners of a square.

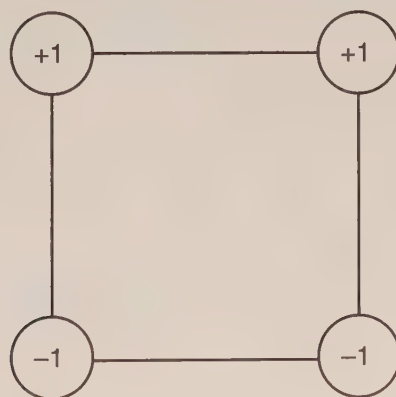
5. What is the force on the -2 charge?



6. What is the force on the lower +1 charge?



7. What is the force on the +2 charge at the center of the square?



Activity 16.3

Magnetic Forces and the Right-Hand Rule

When a charged particle moves in a magnetic field, it experiences a force. The direction of the force is given by the *right-hand rule*. Review this rule in chapter 16.

In the following exercises you will be shown a charged particle. Its velocity, v , will be indicated as well as the magnetic field, B , in the region. Draw an arrow on the charge that represents the direction of the force. If the force is into or out of the page, just write "into page" or "out of page."

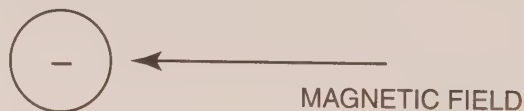
1. A negatively charged particle moves to the right. The magnetic field points into the page.



2. A positively charged particle moves up. The magnetic field points to the left.



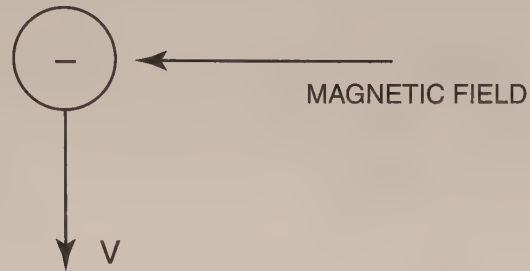
3. A negatively charged particle moves into the page. The magnetic field points to the left.



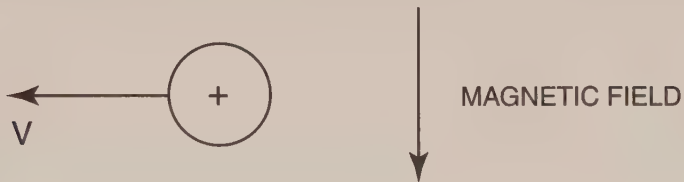
4. A positively charged particle moves out of the page. The magnetic field points down.



5. A negatively charged particle moves down. The magnetic field points to the left.



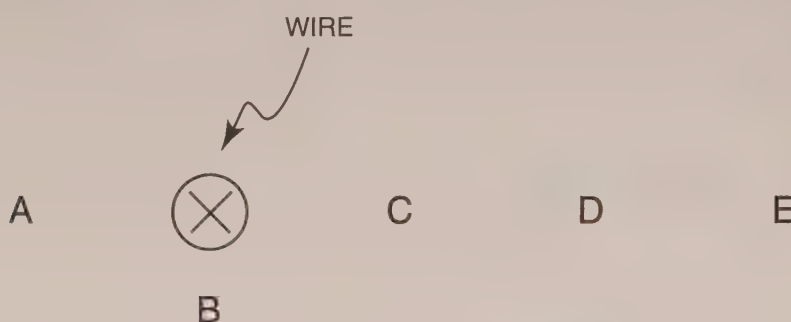
6. A positively charged particle moves to the left. The magnetic field points down.



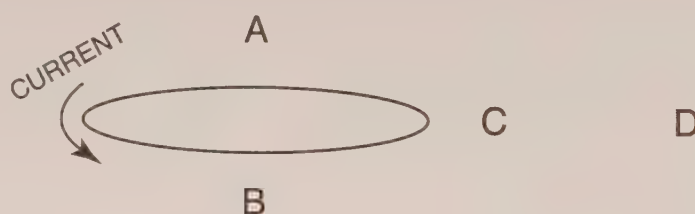
Activity 17.1**Magnetic Fields from Electric Current**

In chapter 17 you learned that moving electric charges create magnetic fields. In the following exercises you will be asked to determine the direction of the magnetic field created by various electric currents.

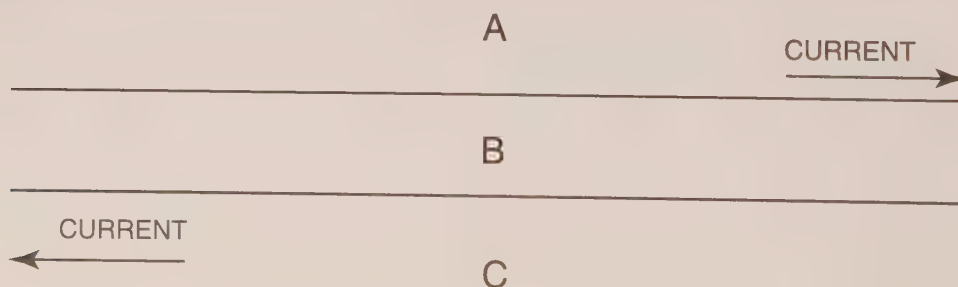
1. The figure represents a long straight wire carrying current into the page. Draw arrows at A, B, C, D, and E that represent the direction and relative strength of the magnetic field at those locations. (Longer arrows mean stronger fields.)



2. A circular loop of wire carries current counterclockwise as viewed from above. Draw arrows at A, B, C, D, and E that represent the direction and relative strength of the magnetic field at those locations. (These locations are in a plane perpendicular to the plane of the loop and bisecting the loop.)



3. Two long straight wires carry current of equal magnitude in opposite directions, as shown.



Select the location, A, B, or C, where

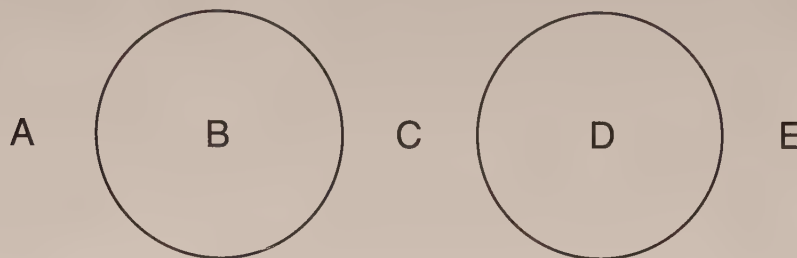
the magnetic field is the strongest _____

the magnetic field is zero _____

the magnetic field points up (out of the page) _____

the magnetic field points down (into the page) _____

4. Two circular loops carry the same amount electric current.



Suppose the current runs clockwise as viewed from above in both loops. What is the direction of the magnetic field at A, B, C, D, and E?

A _____

B _____

C _____

D _____

E _____

Suppose the current runs clockwise in the left loop and counterclockwise in the right loop. What is the direction of the magnetic field at A, B, C, D, and E?

A _____

B _____

C _____

D _____

E _____

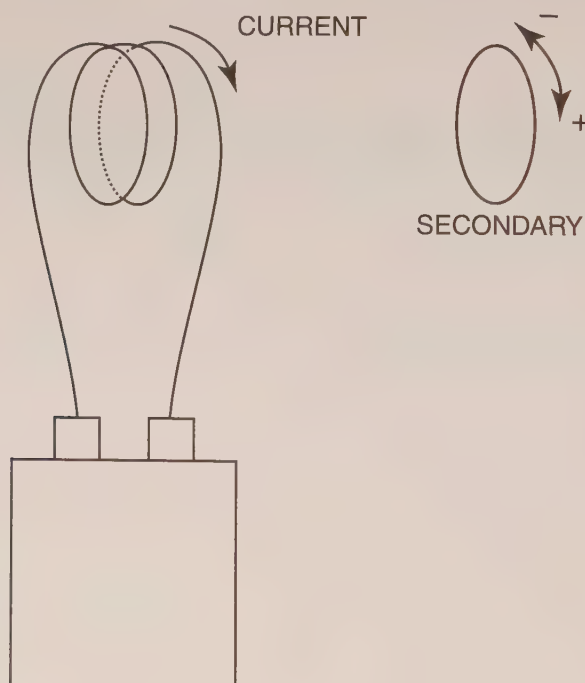
Activity 17.2**Lenz's Law**

Changing magnetic fields create electric fields. These electric fields can drive an electric current in a loop of wire. This is the principle behind the generation of electricity in electrical generators. The direction of the induced current is given by Lenz's law: *The direction of induced current is such that it opposes the change that produces it.* In this activity you will gain experience using Lenz's law. Review chapter 17 as necessary.

TRUE OR FALSE

- _____ Holding a bar magnet near a coil of wire will make current flow through the wire.
- _____ Only increasing magnetic fields generate electric fields.
- _____ Lenz's law is actually a statement of conservation of energy.
- _____ Tilting a loop while it is in a magnetic field will generate current in that loop.

Consider the primary coil of wire connected to a battery as shown. The battery drives an electrical current and the direction is indicated by an arrow. We are interested in the direction of the current induced in the secondary loop on the right. Indicate + or - for the direction of the induced current in the following situations.



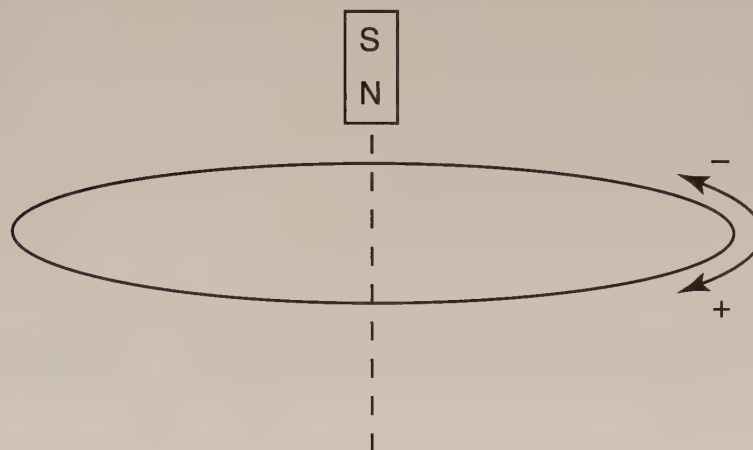
_____ The primary coil is moved towards the secondary coil.

_____ The secondary coil moves towards the primary coil.

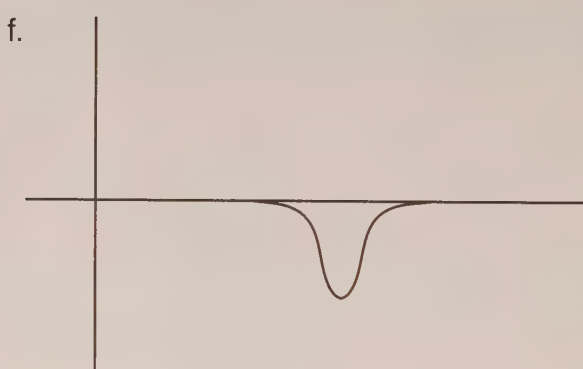
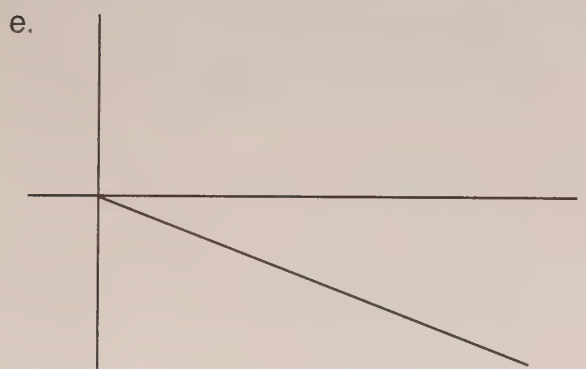
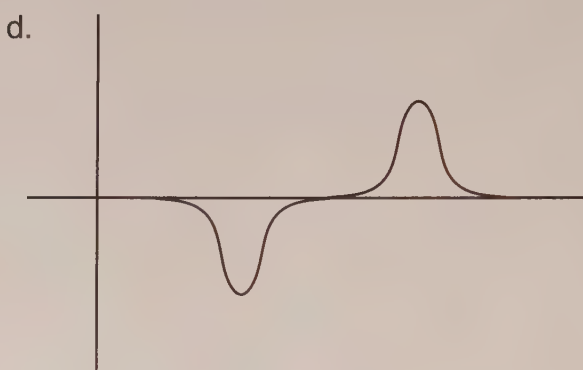
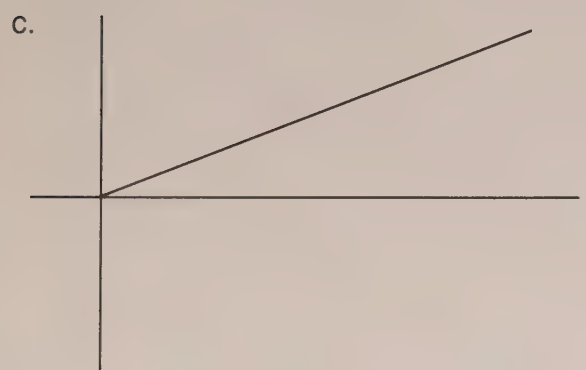
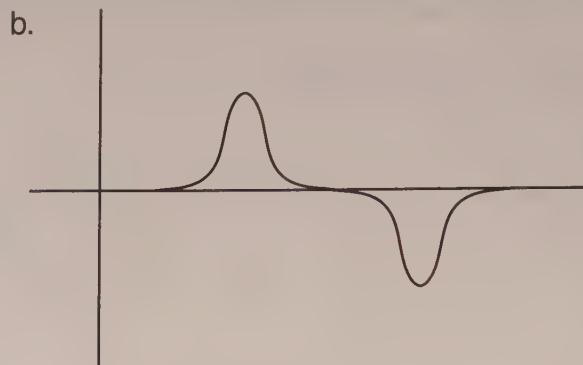
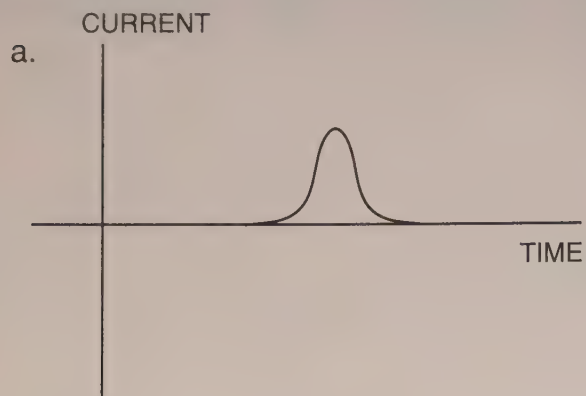
_____ The primary coil is turned around 180 degrees.

_____ The primary coil is shut off.

Consider dropping a bar magnet through a circular loop of wire, as shown in the figure.



Which graph below would represent the current as a function of time through the circular wire?
 We take positive current as clockwise when looking down on the loop. _____



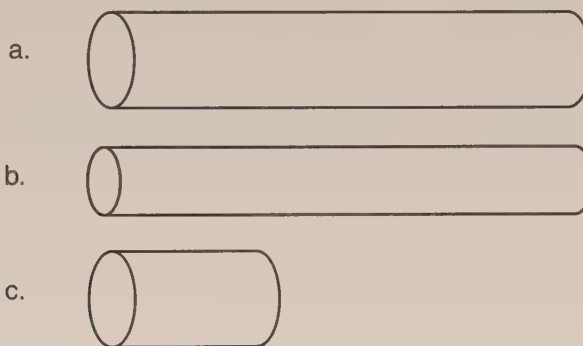
Activity 18.1**Electric Circuits**

Electric circuits can be found literally everywhere in your daily life. What are the three essential parts of an electric circuit?

If an electric circuit is carrying a current of $1/2$ ampere, how many electrons pass a given point in that circuit in a time of 2 seconds? _____

What is the unit of electrical resistance? _____

The figure shows a magnified view of three pieces of copper wire. If a battery is connected to the ends of the wire, electric current will flow through the wire.



In which wire will the current be the greatest? Explain.

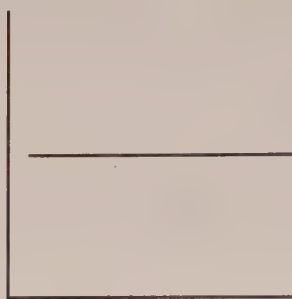
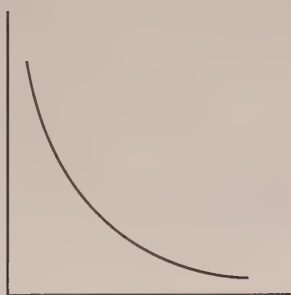
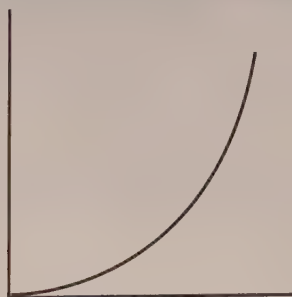
In which wire will the current be the least? Explain.

A 12 volt battery is connected across a resistor whose resistance can be varied. Which of the following graphs represents the current as a function of resistance for this setup?

CURRENT



RESISTANCE

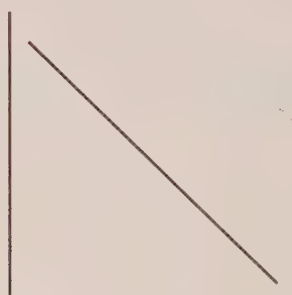
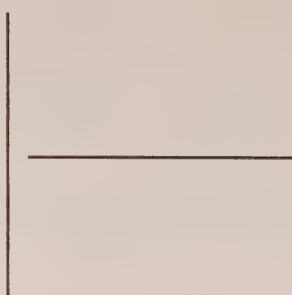


A battery whose voltage can be varied is connected across a 100 ohm resistor. Which of the following graphs represents the current as a function of the voltage for this setup?

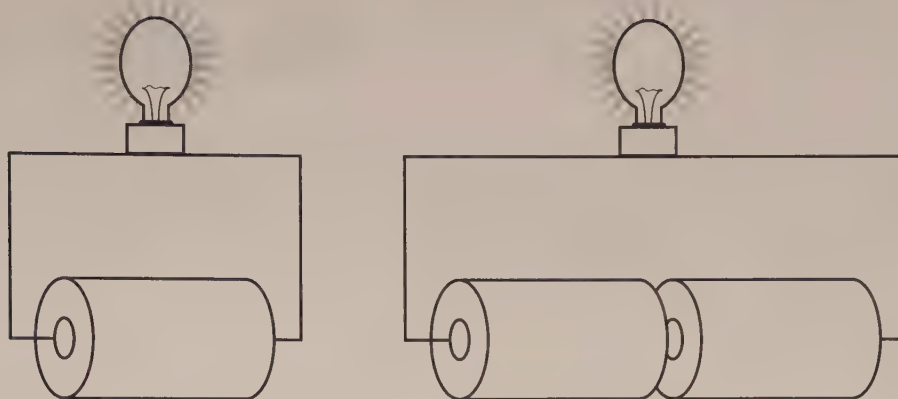
CURRENT



VOLTAGE



Consider the two circuits pictured below which are lighting identical light bulbs. In fact, the circuits themselves are identical except the one on the right has two 1.5 volt batteries in series, and the one on the left has a single 1.5 volt battery.



Which light bulb is consuming more power? _____

How much more power is it consuming? Explain.

Activity 18.2**Electrical Safety**

Each year in the United States, about 500 people are electrocuted in their homes or workplaces. When in your home you are literally surrounded by potentially dangerous high-voltage sources of electricity. In this activity you will research some aspects of electrical home safety and report your findings. An internet search on "electrical safety" should yield many pages of useful information.

What is a circuit breaker?

What is a fuse?

If an appliance repeatedly blows a fuse or trips a circuit breaker, you should:

- replace the fuse or circuit breaker with one with a larger current rating.
- keep replacing the current fuse or resetting the current circuit breaker.
- plug the appliance into a different outlet.
- unplug the appliance and have it repaired or replaced.

Why are halogen lamps more of a fire hazard than ordinary lamps?

- a. halogen lamps become much hotter than ordinary lamps.
- b. halogen lamps use much more current than ordinary lamps.
- c. halogen bulbs tend to break, exposing the filament.
- d. halogen gas is flammable.

Why is the human body a good conductor of electricity?

What amount of current running through your body would probably be fatal?

How come birds can sit on utility lines safely, but humans are strongly advised not to climb utility poles and touch the lines?

How does a three pronged plug work and why are they used?

What is a polarized plug and why are they used?

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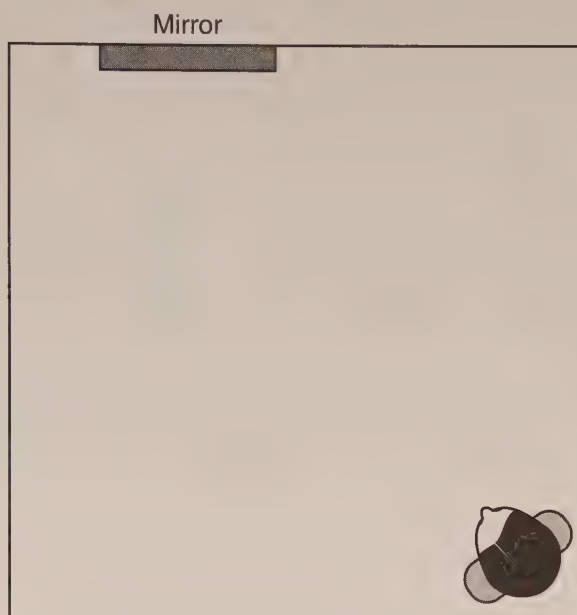
What is a "GFCI" and what is its purpose?

How do GFCI's work?

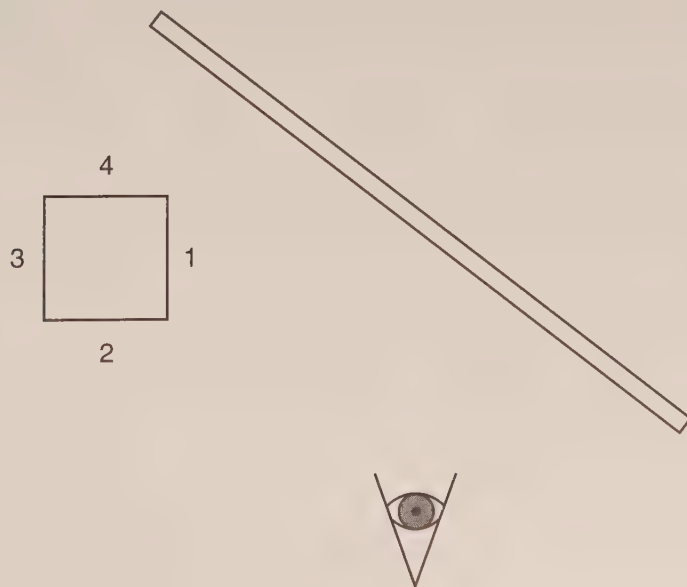
Activity 20.1

Reflection

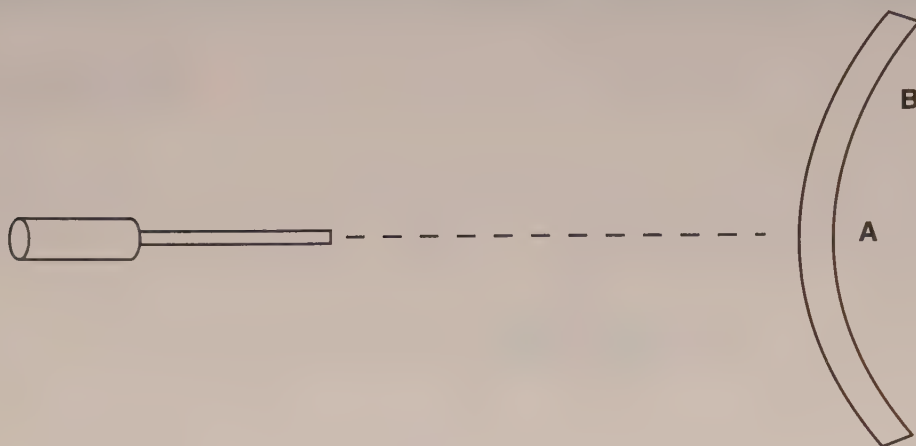
The figure is an overhead view of a person standing against a wall in a square room. There is a flat mirror on the opposite wall. What parts of the room can he see in the mirror? Indicate these regions by marking the walls of the room.



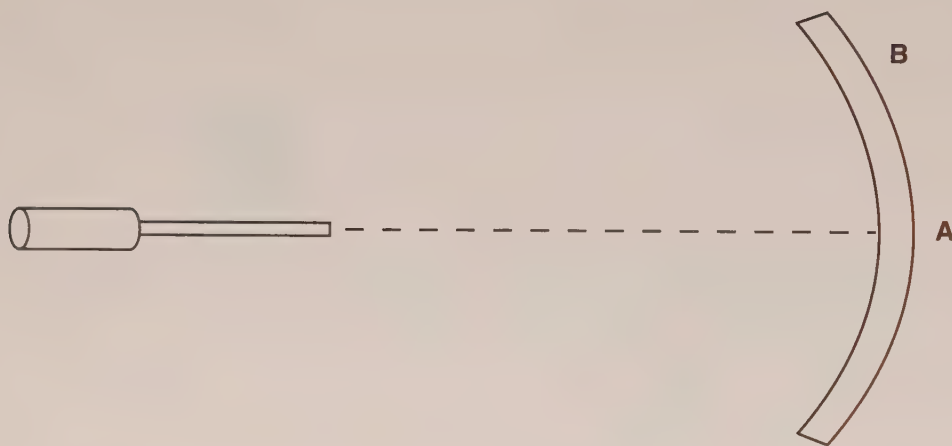
Consider the cube sitting in front of a flat mirror. If you are looking at the mirror from point P, which face of the cube will you see as you look towards the mirror?



A laser beam is aimed at a convex spherical mirror as shown. Sketch the incident and reflected ray if it is aimed at point A. Do the same for point B.

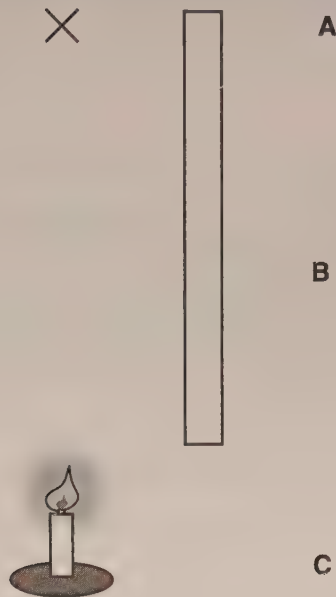


A laser beam is aimed at a concave spherical mirror as shown. Sketch the incident and reflected ray if it is aimed at point A. Do the same for point B.



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A candle sits near a flat mirror. Where would somebody standing at X see the image of the candle? (Answer D if the image cannot be seen.) _____



A common Halloween prank is to surprise trick-or-treaters with the 'living head on a table' gag. This can be accomplished with a four legged wooden table and two flat mirrors. How is this trick done? Sketch the setup in the space below.

Activity 20.2

Refraction

When light travels from one medium (water, for example) to another (glass, for example), the light beam changes direction. The amount of direction change depends on the relative indices of refraction of the two media and the incident angle.

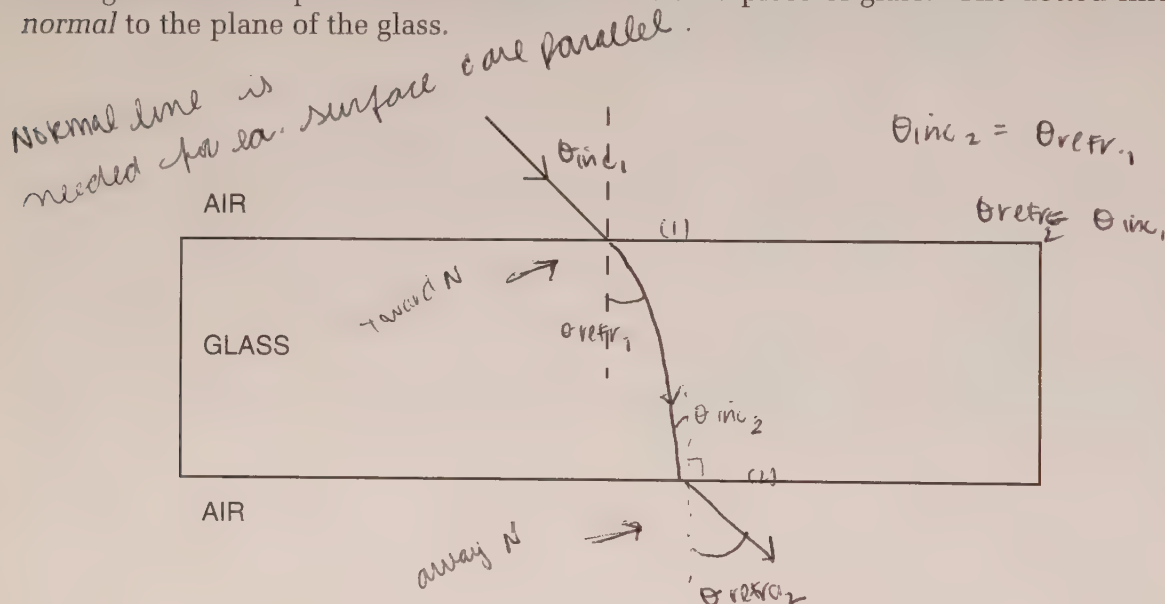
1. If the index of refraction of a certain type of glass is 1.5, what is the speed of light in that glass?

$$n = \frac{c}{v} = 1.5$$

$$v = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{1.5} = \boxed{2.5 \times 10^8 \text{ m/s}}$$

2. True or false: When a light beam travels from one medium to another, the light always bends *towards* the normal. false
3. True or false: Light travels faster in a vacuum than any other material. true

The figure below depicts a laser beam incident on a piece of glass. The dotted line is the *normal* to the plane of the glass.



4. Sketch the beam as it travels through the glass and out the other side.
5. If someone were looking up at the glass from point P, where would the laser be seen? Redraw the laser at this location.
6. Is this displacement of the image due to refraction more severe for thick glass or thin glass?
- _____

7. Which is faster: running on the beach, or swimming in the water? _____
8. A lifeguard at L has to save a person swimming at X. Draw the path the lifeguard should take so that she will reach the swimmer in the least amount of time. (If you don't know the answer, do an internet search on "Fermat's principle".)

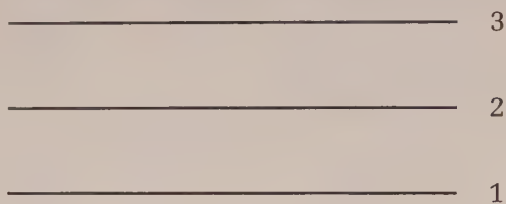


9. What does this lifeguard/swimmer example have to do with light and refraction?

Activity**21.1****Electron Transitions in Atoms**

Electrons in atoms occupy discrete energy levels. When an electron jumps from a higher level to a lower level, a photon is emitted whose energy is equal to the energy difference between levels. In the following questions, the energy levels in atoms are represented by horizontal lines, and the distance between the lines is proportional to the energy difference between levels.

1. Suppose an atom has three equally spaced energy levels.

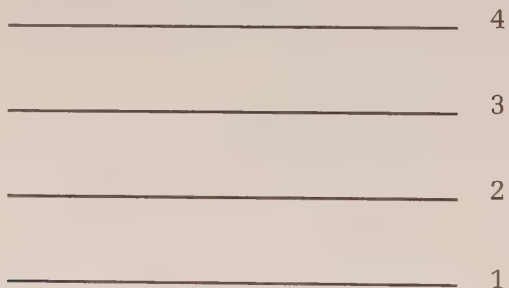


How many possible downward jumps (from higher to lower energy) could an electron make in this atom? _____

How many different photons would result from all possible electron jumps in this atom?

Which jump(s) would result in the highest frequency photon? _____

2. Suppose an atom has four equally spaced energy levels.

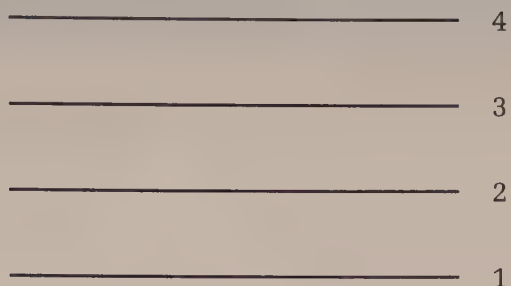


How many possible downward jumps (from higher to lower energy) could an electron make in this atom? _____

How many different photons would result from all possible electron jumps in this atom?

Which jump(s) would result in the longest wavelength photon? _____

3. Suppose an atom has four energy levels, as shown.



How many possible downward jumps (from higher to lower energy) could an electron make in this atom? _____

How many different photons would result from all possible electron jumps in this atom?

Which jump(s) would result in the highest energy photon? _____

4. Suppose a gas discharge tube emits light that consists of five different wavelength photons. Construct an energy level diagram (as shown above) that would be consistent with an atom that emits five different photons.

5. Repeat number 4 for a discharge tube that emits six different photons.

Activity 22.1**Uncertain Times**

One of the central principles of quantum mechanics is Heisenberg's uncertainty principle. Basically the uncertainty principle says that you cannot simultaneously determine the position and momentum of an object with perfect accuracy. Because of the extremely small value of Planck's constant, the uncertainty principle only manifests itself for very small objects (like atoms and subatomic particles). In this activity we will see how the uncertainty principle would affect everyday life by assuming Planck's constant is **much** larger: $h = 1\text{kg} \cdot \text{m}^2/\text{s}$ (instead of the correct value of $h = 6.63 \times 10^{-34}\text{kg} \cdot \text{m}^2/\text{s}$). The uncertainty principle reads, $\Delta x \times p > h$. Since momentum (p) equals mass times velocity, we can write this as $m \times \Delta x \times \Delta v > h$, or

$$\Delta x \times \Delta v > h/m$$

1. If you took a meter stick and measured the position of a baseball on your desktop to an accuracy of $\pm 1\text{mm}$ or $\pm 0.001\text{m}$, what is the uncertainty in the baseball's velocity? (Assume the baseball has a mass of 0.5kg .)

Ordinarily you could just look at the baseball and be certain that its velocity is zero. What does the above result mean?

2. As you drive down the road, you look at your speedometer and you see that you are going 10 miles an hour. The uncertainty in your knowledge of your speed is ± 0.5 miles/hour, which is about ± 0.25 m/s. What is the uncertainty in the position of your car? (Assume the car has a mass of 1000 kg.)

Does this seem reasonable? Do you think it's possible, with modern day equipment, to measure the position of a car to greater accuracy?

3. You see a large wasp in your bedroom and sprint out and close the door. Your bedroom measures 5 meters on a side. As you stand outside your bedroom, wondering what to do, what is the uncertainty in the wasp's speed? (Assume the wasp has a mass of 5 grams.)

Does it make sense that you would not know the speed of the wasp if you're not in the room with it? Does this mean that the uncertainty principle actually does apply to large objects? Explain.

4. Make up your own example of an application of the uncertainty principle to everyday objects. What is the situation?

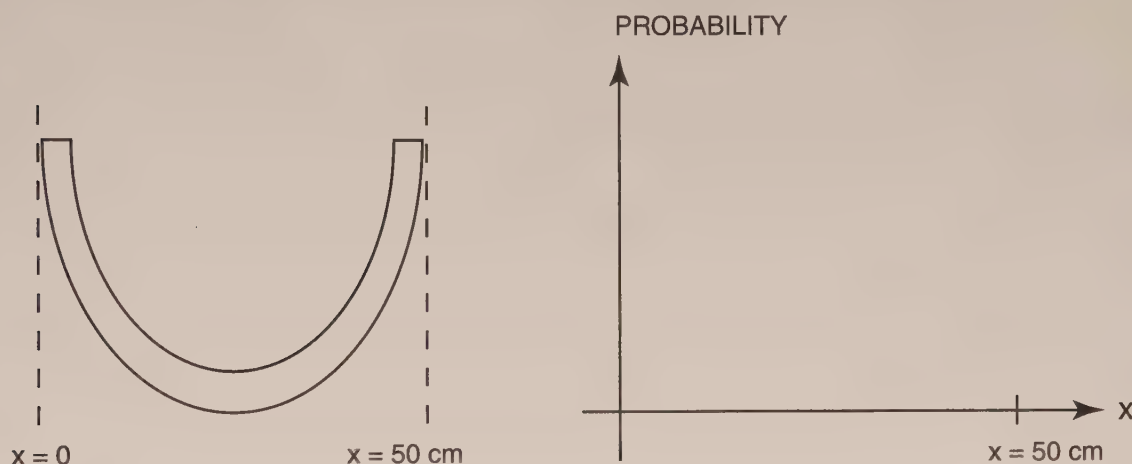
What is the uncertainty?

Discuss your result.

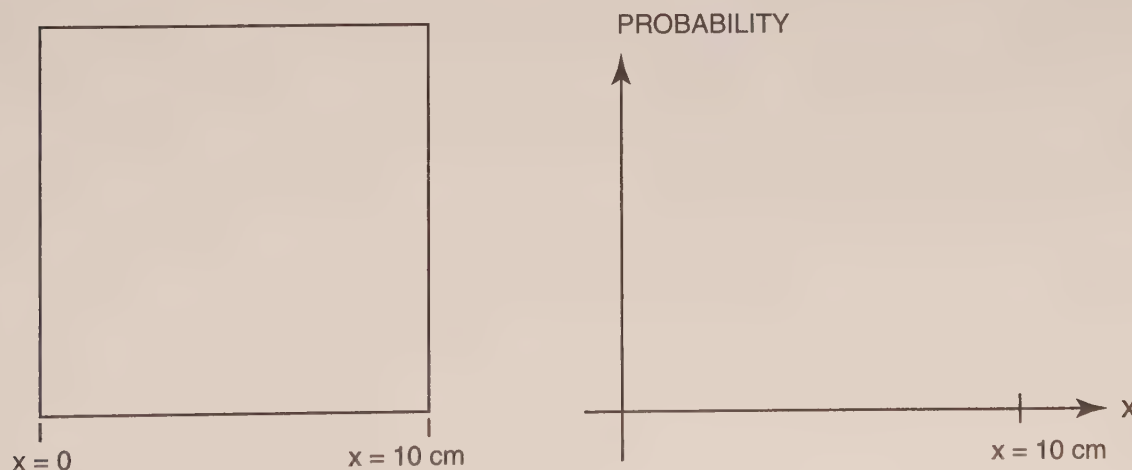
Activity 22.2**Probability Graphs**

The *wave function* of a quantum object is a set of probabilities that predicts the likelihood of finding the object in a particular location. Wave functions can be represented on probability graphs, as discussed in chapter 22. In the following exercises, you will be given a description of an object and its situation. For each object, make an approximate probability graph. The position of the object will be denoted by x . Be sure to label your x axis.

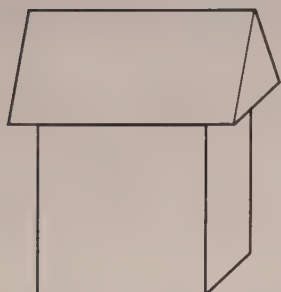
1. A marble is confined to the interior of a rounded bowl. If this is all the information you have available, construct an approximate probability graph for the location of the marble.



2. A metal cube 10 cm on a side is completely evacuated except for a single hydrogen atom. You have no information about the whereabouts of the atom except that it is inside the box.



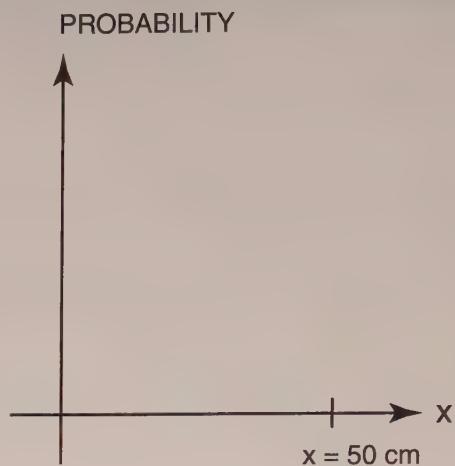
3. John lives alone in a house in the woods. Except for occasional trips to the outhouse, he spends all of his time inside the house.



$x = 0$



$x = 50 \text{ cm}$



4. Make up your own example in the space below.

Activity 23.1

Composite Materials

Composite materials combine the properties of two or more materials. Usually the purpose is to create a material that has more strength. In this activity you will research some composite materials and report your findings.

COMPOSITE CORE POWER LINES

Describe the construction of traditional power lines.

What is a composite core power line? What materials are used?

What is the primary advantage of composite core power lines over traditional power lines? Can they carry more electricity?

FIBERGLASS

What are the raw materials used in making fiberglass?

Find at least two examples of construction materials that fiberglass has largely replaced in the last 30 years.

What is the advantage of fiberglass over the other materials?

SAFETY GLASS

Safety glass is frequently used in automobile applications. What is safety glass?

How is safety glass constructed?

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BULLETPROOF GLASS

What is the difference between bulletproof glass and safety glass?

How is bulletproof glass constructed?

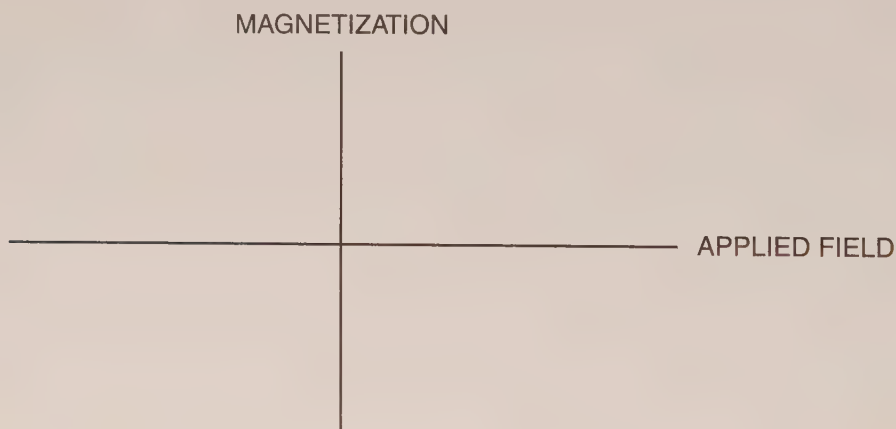
Activity 24.1**Magnetic Recording**

One of the most important applications of ferromagnetic materials is in magnetic recording devices like computer disks and magnetic recording tape. In this activity you will be asked to research magnetic recording and report on your findings.

1. What is a ferromagnetic material?

2. What is a hysteresis curve?

3. Sketch a hysteresis curve on the graph below.



4. Explain the meaning of the hysteresis curve.

5. What is *remnant magnetization*?

6. Describe the role of the electromagnet in the magnetic recording system recording system.

7. Are writeable CD's an example of magnetic recording? Explain.

Activity 25.1**Binary**

Computers store information in binary form. All letters and numbers can be represented by a series of 1's and 0's. In chapter 25 we learned that the 26 letters of the alphabet can be represented by 5 bits of information. Create your own binary representation of the alphabet by filling in the table below.

LETTER	BINARY CODE	LETTER	BINARY CODE
A		N	
B		O	
C		P	
D		Q	
E		R	
F		S	
G		T	
H		U	
I		V	
J		W	
K		X	
L		Y	
M		Z	

Numbers can be represented in binary also. The number 13 is represented by 1011. Each digit represents a power of 2:

1 1 0 1

$$1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 13$$

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To help with the rest of this activity, calculate the following numbers with your calculator:

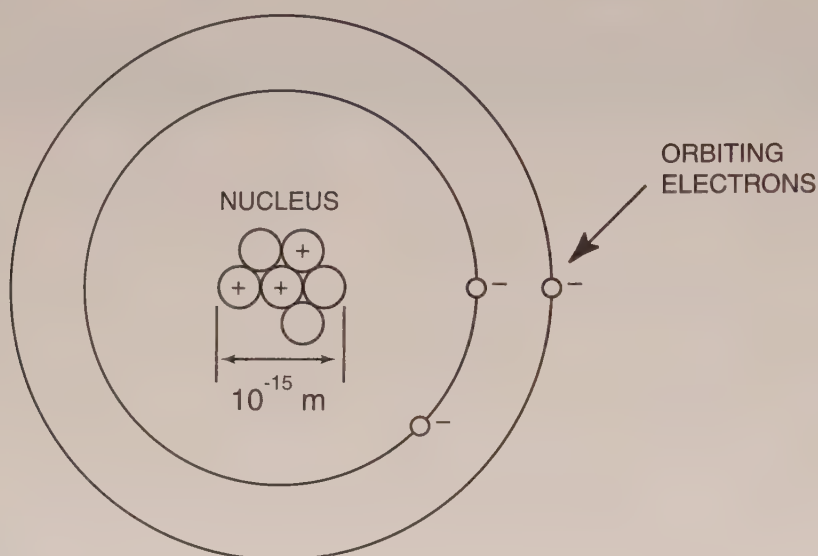
$2^0 =$	$2^5 =$	$2^{10} =$
$2^1 =$	$2^6 =$	$2^{11} =$
$2^2 =$	$2^7 =$	$2^{12} =$
$2^3 =$	$2^8 =$	
$2^4 =$	$2^9 =$	

Fill in the following table of numbers with their binary equivalents.

NUMBER	BINARY EQUIVALENT
0	
10	
18	
43	
56	
544	
1026	
2450	
1111	
5325	

Activity 26.1**Nuclear Dimensions**

In chapter 26 you learned that atoms are mostly empty space. The atom consists of a nucleus and electrons orbiting it. Consider the schematic diagram of an atom below. In this activity we will consider the size of your body if we eliminated all of the empty space in it by packing the nuclei close together.



1. Assuming the atom is spherical, calculate the volume of the atom. (The volume of a sphere is $\frac{4}{3}\pi R^3$, where R is the radius of the sphere.)
2. Assuming the nucleus is spherical, calculate the volume of the nucleus.

3. If this atom is representative of atoms found in normal matter, what fraction of normal matter is empty space? What fraction is actually matter?

4. Estimate the volume of your body in cubic meters. (Assume you are rectangular and estimate your height, depth, and width.)

5. Estimate the volume of actual matter in your body using the answer to number 3. If all of the matter (the atomic nuclei) in your body were packed into a small sphere, what would the radius of this sphere be?

6. Could all of the matter in your body fit onto the head of a pin? Explain.

7. What would be the practical difficulties in trying to pack nuclei very close together?

Activity 26.2**Radioactivity**

How many protons and neutrons are in the following nuclei?

NUCLEUS	# PROTONS	# NEUTRONS
Carbon-12		
Silicon-24		
Iron-59		
Nickel-55		
Promethium-138		
Ytterbium-160		

When a radioactive nucleus decays by alpha or beta decay, it changes into a new element. Determine the product of the following radioactive decays.

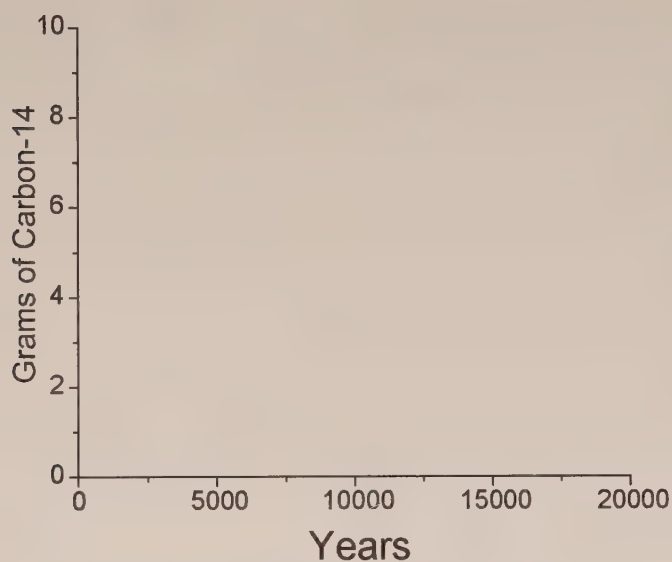
RADIOACTIVE NUCLEUS	DECAY MODE	DAUGHTER NUCLEUS
Hydrogen-3	beta	
Carbon-14	beta	
Oxygen-15	beta	
Hafnium-156	alpha	
Radon-212	alpha	
Thorium-228	alpha	
Americium-241	alpha	
Americium-244	beta	
Uranium-238	alpha	
Sodium-25	beta	

The half-life of a radioactive nucleus is the amount of time it takes for half of a large sample of those nuclei to decay.

CARBON-14

Carbon-14 decays by beta decay. What does carbon-14 turn into when it decays?

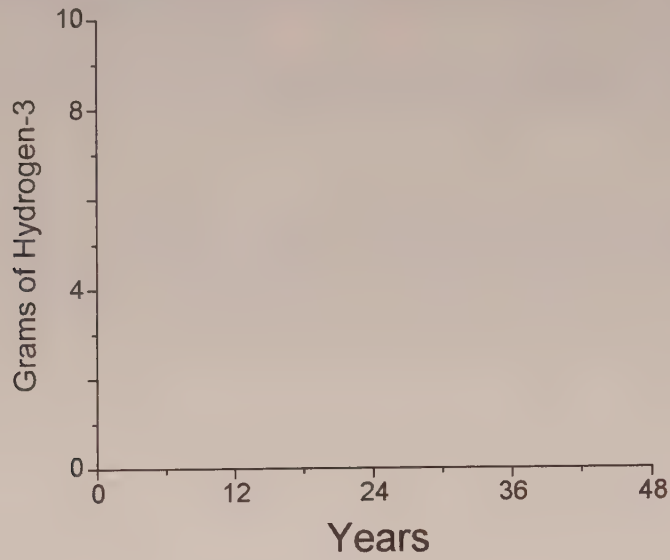
The half-life of carbon-14 is roughly 5000 years. Assuming you start with a 10 gram sample of carbon-14, plot the amount left versus time on the graph below.



HYDROGEN-3

Hydrogen-3 (also known as tritium) decays by beta decay. What does hydrogen-3 turn into when it decays?

The half-life of hydrogen-3 is roughly 12 years. Assuming you start with a 64 gram sample of hydrogen-3, plot the amount left versus time on the graph below.



Activity 26.3**Radioactivity Around The Home****AMERICIUM-241**

Most smoke detectors contain an artificially produced isotope: americium-241. Do some research into the operation of smoke detectors and answer the following questions.

1. Why do smoke detectors use radioactive isotopes? Describe the function of radioactivity in the operation of the smoke detector.

2. How is americium formed?

3. What is the half-life of americium-241? Based on this half-life, how long would you expect the smoke detector to operate without having to replace the radioactive source inside?

4. If possible, find the manual for a smoke detector. Photocopy it and staple it to this page before turning it in.

5. Do you think the additional safety of using smoke detectors outweighs the risks associated with having americium-241 in the home? Explain.

RADON

Radon-222 is a radioactive gas that is associated with certain types of cancer. Many homes around the world have levels of radon that are considered unsafe.

6. Where does radon enter the home?

7. Why is radon considered more dangerous to smokers than non-smokers?

8. How is radon-222 created? (What parent nucleus decays into radon-222?)

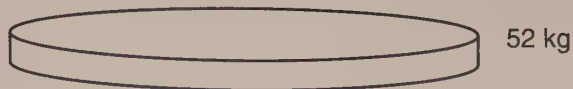
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9. How does a radon testing device work?

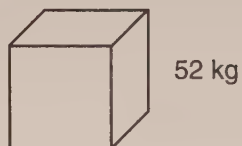
10. If unsafe levels of radon are found in your home, what can be done?

Consider the following configurations of uranium-235. Would you expect any of these to be a critical mass? Explain your reasoning.

52 kilogram disk of uranium-235:



52 kilogram cube of uranium-235:



60 kilogram sphere of uranium-235:



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50 kilogram sphere of uranium-235:



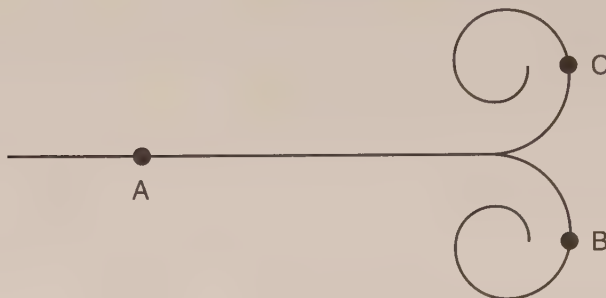
Activity 27.1

Particle Tracks

The goal of high energy particle physics is to discover the types of elementary particles and how they interact with each other. In a typical experiment, particles (protons or electrons, for example) are given tremendous kinetic energy by a particle accelerator. Then they are forced to collide with each other, or with another target producing a number of other particles in the process. One of the most complex aspects of this type of experiment is the detection of the particles created in the collisions. The tracks they leave in the detector tell physicists much about the collision.

The following figures represent tracks of particles in a region where a magnetic field exists. The magnetic field points into the page.

1. Particle A, moving left to right, decays into particles B and C.



What is the charge of particle A? _____

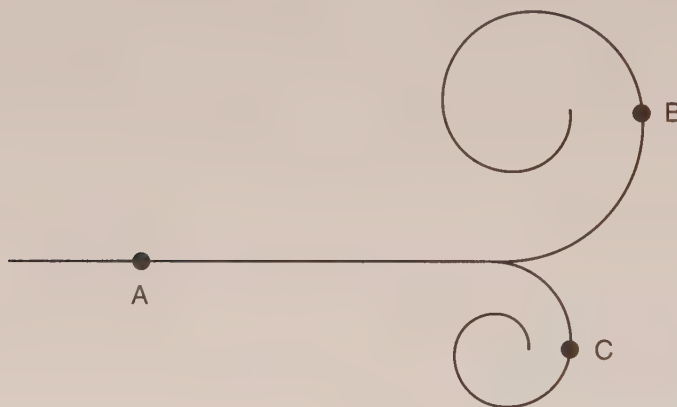
What is the charge of particle C? _____

2. Particle A, moving left to right, decays into particles B and C.



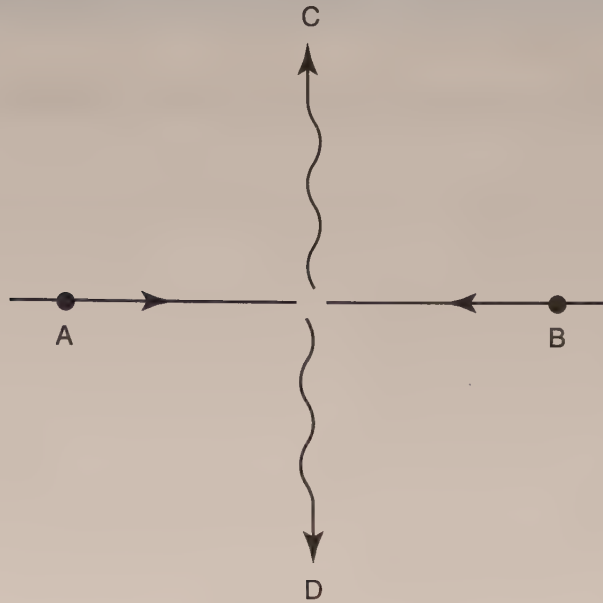
Explain why these tracks are impossible. (Hint: think about conservation of charge.)

3. Particle A, moving left to right, decays into particles B and C.



Assuming B and C have equal and opposite charges, which one is more massive? Explain.

4. Particles A and B come together horizontally, annihilate, and two photons leave vertically, as shown.



Compare the charge of A to the charge of B.

Can you say anything else about particles A and B?

Compare the wavelength of photon C to photon D. Explain.

Activity 28.1**Time Dilation and the Twin Paradox**

In this activity you will study time dilation and the famous Twin Paradox in Special Relativity. Be sure to review the *Looking Deeper: The Size of Time Dilation* section in the text.

Imagine that your twin brother takes off in a spaceship and travels at 99.5% the speed of light. According to your ground based clock, he is gone for one year. How much time (according to you) passes on the spaceship?

Now imagine what your brother sees. In his reference frame he sees himself as stationary and he sees you (the Earth) moving at 99.5% the speed of light. According to his watch, how many Earth years pass for each spaceship year?

Why is this situation called a paradox?

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Do some research on the internet and find out how this paradox is resolved. Write your findings in the space below.

What is the key difference between special relativity and general relativity?

Activity 28.2**A Relativity Quiz**

1. You've decided to let your sister, a NASA astronaut, cook the thanksgiving turkey this year. Normally, the turkey will take 6 hours to cook, but your sister decides to cook it on her space-ship while traveling at close to the speed of light. According to your watch, she was gone for 6 hours. The turkey comes back:
 - a. overcooked
 - b. undercooked
 - c. just right
 - d. both undercooked and overcooked
2. According to a person on the surface of the Earth, the clock in a GPS satellite runs _____ because of its relative motion, and _____ because of its higher altitude.
 - a. slow, slow
 - b. slow, fast
 - c. fast, slow
 - d. fast, fast
3. Because of relative motion, you notice a friend's clock running slowly. Your friend notices that your clock is running:
 - a. fast
 - b. slowly
 - c. normal
4. Someone shines a light while moving towards you at 1000 m/s. With what speed will the light strike you? (The speed of light is 300,000,000m/s.)
 - a. 300,000,000m/s
 - b. 300,001,000m/s
 - c. 299,999,000m/s
 - d. any of these are possible

5. If you are in a spaceship far from the reaches of gravity, under what conditions will you feel weightless?
- a. if it is accelerating at just the right rate
 - b. if it is moving uniformly
 - c. if it is spiraling out of control
6. You are riding on a flatbed truck moving at 50 miles per hour. You have two guns, one aimed forward and one aimed backwards and you fire them at the same time. What is the fastest observed speed?
- a. forward moving bullet in the truck's reference frame
 - b. forward moving bullet in the ground's reference frame
 - c. backward moving bullet in the truck's reference frame
 - d. backward moving bullet in the ground's reference frame
7. If you can do 20 pushups on the surface of the Earth, how many can you do in a spaceship, far from gravity, accelerating at g (10 m/s/s)?
- a. 20
 - b. less than 20
 - c. more than 20
 - d. probably hundreds
8. You are jealous of your younger brother, who looks very young for his age. You are interested in reducing the rate at which you age, relative to him. Given the choice, would you work as a park ranger, high in the mountains, or as a taxi cab driver at sea level? (Take into account the effects of gravity only.) Explain your reasoning.

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9. It is well-known that light bends the same amount per second as a thrown baseball. How come a flashlight beam appears to travel in a straight line path?

Activity 29.1

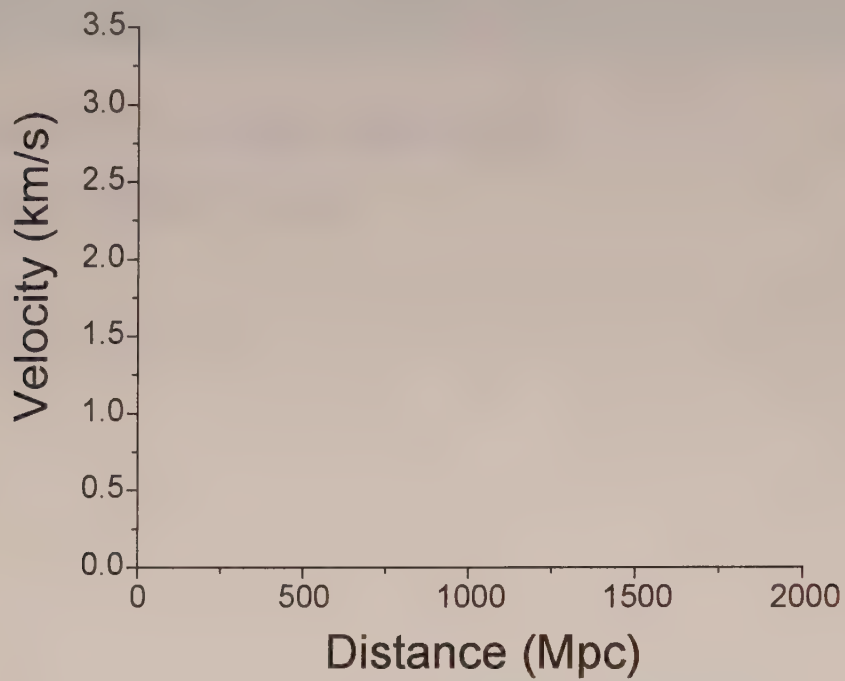
Astronomical Distances and Hubble's Law

The distances we measure in everyday life range from millimeters to kilometers. However, to measure astronomical distances it is more convenient to measure distance in light years or parsecs. Estimate, in years, how long it would take for you to walk one light year. Show your calculation.

Edwin Hubble found evidence that the universe was expanding. (Review Hubble's Law and the redshift in chapter 29.) Suppose that his data were summarized in the following table (instead of Table 29-1):

DISTANCE TO GALAXY (MPC)	VELOCITY (KM/S)
1	250
1.5	750
2	1000
2.5	1300
3	1700

Plot this data in the graph below.



Draw a straight line that best represents this data and calculate the Hubble constant.

What is the approximate age of the universe based on this data?



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